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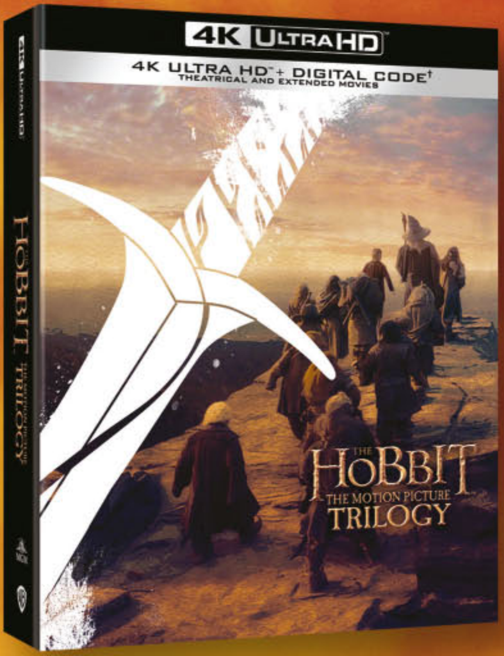
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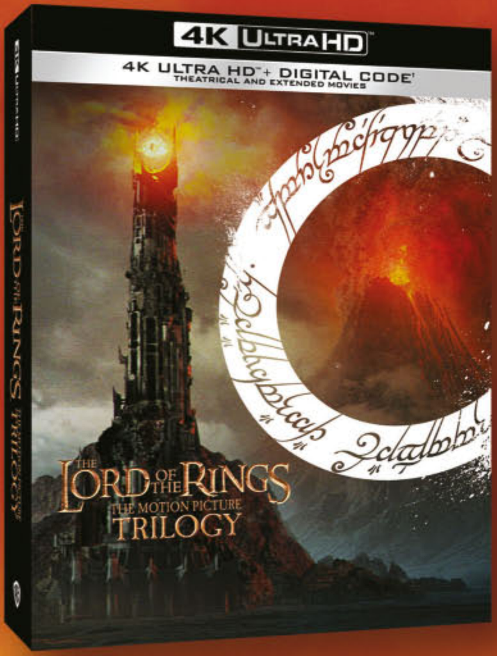
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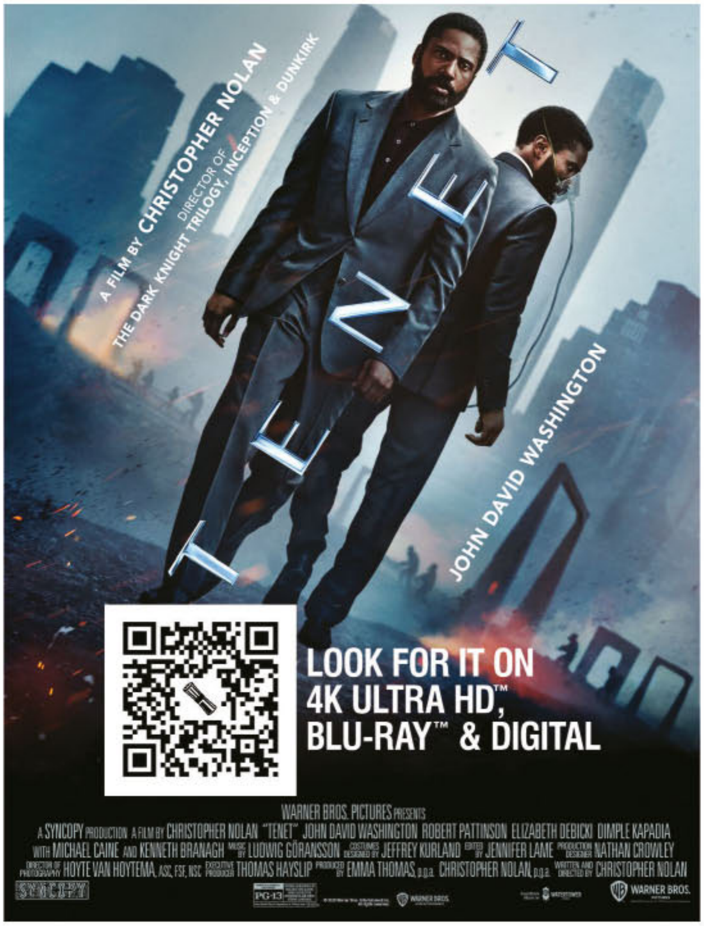
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LOOKING FORWARD

WE'VE FINALLY MADE IT to 2021! And with that, I've gathered the very best technological minds I could find to figure out what exactly is going to launch in the next 12 months. From GPUs, to processors, to SSDs, cooling, and more, 2021 is going to be an exceptionally interesting year. On top of that, it's time for *Maximum PC*'s irregular annual Geek Quiz! Try your mind at some of the most complex, pain-in-the-butt tech questions we've ever devised from this year's news. We've also got features on writing your own OS, setting up a smart home, and a kick-ass full-tower server build with 12TB of WD NAS SSDs!

This issue we also have the Ryzen 9 5900X, the AMD Radeon RX 6800XT, and the Nvidia GeForce RTX 3070 in the lab for analysis, alongside a serious swathe of peripheral goodness, including the Happy Hacking Keyboard that comes in just over the $300 mark. Yeah I still can't get my head around that either. And of course there's a bevy of columns, tutorials, blueprints, and more.

Lastly, if anyone is still having trouble with their subscriptions, or missing issues, please get in touch with me directly at zak.storey@futurenet.com, We seem to have got to the bottom of most of the problems now, but this way I can personally forward on any complaints that haven't been addressed to our team internally, with a bit of the ol' "I'm the boss" leverage.

Zak Storey

Zak Storey is Maximum PC's *editor and long-time staff member. He's been building PCs since he was 10, and is more than capable of butting heads with the biggest names in tech.*

↘ submit your questions to: comments@maximumpc.com

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(Signed) Mark Constance, Head of Production
Date: October 7, 2020

THE NEWS

Apple's M1 Generation

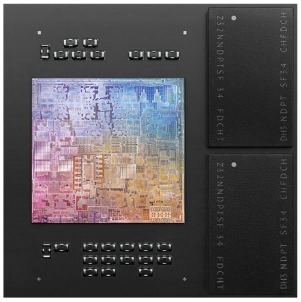
Do we have a serious rival to the x86 architecture?

APPLE'S MOVE away from x86 architecture has begun in earnest with the release of the first batch of machines sporting the Apple-designed M1 processor. This isn't the first time Apple has jumped horses—it started out using Motorola chips in 1983, and stuck with these until 1995 when it switched to PowerPC chips, then in 2006 it moved to Intel x86 silicon. Following the success of the ARM chips in its iPhones and iPads, it has gone and launched new MacBook Pro, MacBook Air, and Mac minis all sporting the new M1 chip, and all considerably faster than their predecessors. Dubbed “the first chip designed specifically for the Mac,” the M1 is a SoC built using a 5nm process. It has four performance cores (Firestorm), and four high-efficiency cores (Icestorm), in a 4+4 big.little design. It's roughly a desktop version of the A14 chip Apple has been putting into its iPhones, only with two more Firestorm cores, and twice the GPU cores. The M1 was built on the back of the experience and revenues the iPhone generated. Apple has at last built the chip it wanted.

Apple made some impressive claims for its new M1-powered hardware, not all of which are strictly true. It said that in a MacBook Air “M1 is faster than the chips in 98 percent of PC laptops sold in the past year.” Even given the huge numbers of Chromebooks sold, can that really be true? It also claims the M1 has the world's fastest CPU core in low-power (whatever that means), the world's best performance per watt, and the world's best integrated graphics, at 2.6 teraflops.

Early benchmarks of the M1 chip are more than encouraging. The chip can hold its own against the most powerful Intel chips Apple put into a MacBook Pro. In single-threaded applications the M1 inside the new Mac mini more than matches an Intel i7-1165G7 (a new Tiger Lake piece). In multi-threaded benchmarks the AMD designs romp away as you might expect, but the M1 comfortably beats similar Intel offerings. It's still early days, but these first tests are an eye-opener. The M1 is a very efficient and competent design, and more than capable of taking its place at the top table.

> Apple has upset the cart with its M1 ARM chip



Switching to an ARM chip of course means a different instructions set: ARM64 rather than x86-64. This does mean it can run iOS and iPadOS apps natively, but any software written for x86 chips will have to be run in emulation. Apple's done this before, as the original switch to x86 Intel chips required this in the form of Rosetta; now we have Rosetta 2. The original Rosetta wasn't terribly good—there was a palpable performance hit, sometimes a huge one. Rosetta 2 works differently, as it translates on installation. It only does real-time translation on things that aren't loaded ahead of time, such as browser processes. This time there won't be a performance drop on changing architectures.

The M1 is the first non-x86 chip for many years that can compete directly with the best x86 has to offer. Companies with ARM licenses are going to notice, manufacturers of kit that isn't wedded to x86 architecture are going to notice. AMD and Intel will certainly notice. Just how committed to x86 is Microsoft? You could build an M1 Windows rig, although Microsoft's current license wouldn't allow it. OK we are getting ahead of ourselves, but M1 shows that there is a viable and competitive alternative, which is going to eat into edges of the x86 market. The M1 is just the start too, Apple has a road-map like any other manufacturer, and rumors are already circulating of a 12-core M2 chip to follow, having eight high-performance cores and four high-efficiency ones (8+4). The shift to ARM power will take about two years to complete, and Apple has pledged to support x86 Macs for “years to come,” although the company has a history of ditching old technology quickly.

The M1's debut hasn't been entirely smooth. There have been “compatibility issues,” including the latest Chrome browser crashing, and nasty reinstallation bugs that can leave your shiny toy bricked.

Good as the M1 undoubtedly is, this is still early days, and we won't be ditching our x86 chips in our gaming rigs anytime soon, but the M1 is a reminder that you cannot take anything for granted. **–CL**

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GOVERNMENT RECOVERS STOLEN SILK ROAD PROCEEDS

SILK ROAD WAS A HIGHLY CONTENTIOUS dark-web marketplace launched in 2011, and shut down by the FBI in 2013. Payments for its dubious offerings were made in Bitcoin. Its creator, Ross Ulbricht, was hit by hackers, and had over 70,400 Bitcoins stolen. Apparently the coins had been stolen in increments while Silk Road was operational, and have been sitting in an account ever since. Recovering lost Bitcoin is difficult, and as Silk Road acted as a "tumbler" to hide the transactions, following the blockchain wouldn't work.

After much data analysis, law enforcement agents have caught up with the stolen coins, and the unnamed hacker who originally purloined them has signed a forfeiture agreement and handed the coins over to the government. At the time the coins were originally stolen they were worth about $9.5 million; this has jumped to over $1.26 billion, as Bitcoin's volatile value has been on something of a surge recently. Quite a haul. **–CL**

FIRST DISCRETE INTEL XE GPUS

Intel prepares to be the third graphics player

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GRAPHICS

INTEL'S ASSAULT on the GPU market took another step with the release of discrete GPUs for system builders. At the bottom of the stack is the Xe-LP, branded Intel Iris Xe Max. This is essentially what we've seen coupled to a CPU on the Tiger Lake chips. It delivers moderate gaming performance, but it's not being marketed as a gaming chip—Intel pushes "content creation." It runs with a peak clock of 1,650MHz, and has 96 EUs (Execution Units). The Xe-HP is aimed at data centers, and is currently with developers, notably the Argonne National Laboratory. Meanwhile, the design for Xe-HPC (the supercomputers version) has been finalized. The first discrete graphics card, DG1, is a low-end affair, due shortly. We'll have to wait for DG2, the Xe-HPG card, for a real glimpse of what Intel has in store for enthusiasts. This is due next year, and is rumored to be pitched against the GeForce RTX 3070, which means 512 or so EUs. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **MICROSCOPIC VOYAGES**
Researchers have 3D-printed a "micro-swimmer" USS Voyager just 0.015mm long, with its own chemical propulsion system.

✓ **80GB AMPERE**
Nvidia has upgraded its A100 cards to 80GB of HBM2E memory, capable of shifting data at over 2TB per second.

✓ **176 LAYERS**
Micron has started shipping the world's first 176-layer 3D NAND (two 88 layers chip-stacked).

TRAGEDIES

✗ **PIXEL FAILURES**
Google's Pixel Slate didn't sell well, and are now starting to suffer flash memory failures.

✗ **ARECIBO OBSERVATORY**
Failed support cables have left the iconic 1,000-foot diameter radio telescope too badly damaged to fix.

✗ **THINGS YOU DON'T NEED**
How about spending $300 on the Revolution R180 toaster, complete with a touchscreen? And it only fits two slices.

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GOOGLE PHOTO ENDS UNLIMITED STORAGE

You'll have to start paying from next June

GOOGLE IS to start charging for Google Photos from May 31 if you want to store more than the free 15GB that comes with every Google account (which is shared by Google Drive, Gmail, and Photos). Currently images uploaded at high compression don't count towards the total. Only Google Pixel owners will be excluded from the new deal. Why the change? Because free unlimited storage is an open invitation for people to fill countless rack-mounted hard drives with pictures of their cat. Google claims that 28 billion images and videos are uploaded every week, and that the total number of photos has topped 4,000,000,000,000. One piece of good news is that anything added before the new policy kicks in won't count, so if you do have a huge library of images you won't have to find it a new home, or start paying. There are other changes at Google Drive too: From June next year all documents will count towards your quota—every Google Doc, Sheet, Slide, Form, etc. Existing files are exempt, but only if you don't edit them.

Google also reckons that 80 percent of people can store about three years' worth of images on the free 15GB. Which presumably means that 20 percent cannot. Google has over 1.5 billion accounts. Buying extra space with Google One starts at $1.99 a month for an extra 100GB, and goes up from there. A little bit of math here, and you can see one attraction of the changes. Naturally, if you take away something that was previously free, people get disgruntled, and some are accusing Google of buying market share at a loss, before switching to a paid model. However, realistically it couldn't last: Put the words "free" and "unlimited" together and it can't survive market forces forever, somebody is paying for it. We'll just have to take fewer shots of our pets. **–CL**

POLICE AT THE DOOR

Can we live-stream from your house?

THE POLICE IN JACKSON, Mississippi have asked residents to connect their Ring smart doorbells to its Real Time Crime Center as part of a trial. Amazon, keen to create some space, says it is not involved in any way with the scheme, and the decision to share lies wholly with the Ring owner, so if your civil rights are infringed it's not its fault. If such permission is granted the police can happily view all the comings and goings at your house, and any other property within view. Normally surveillance cameras are limited to public spaces, and cannot be directed where somebody has a reasonable expectation of privacy, such as being trained on household doors or windows. However, Ring doorbells could be pointed anywhere; by their nature they are on private property, so side-step the normal regulations. So, if a neighbor's Ring happens to cover your porch too, the authorities have a live feed of the activity at your house as well. The privacy group Electronic Frontier Foundation has claimed that the deal means "our worst fears have been confirmed;" it wants camera systems that are accountable and transparent.

This isn't the first time the Ring system has cause a fuss. You might think that video streams on your property, taken by a device you own, would be your property. They aren't. If you read the terms and conditions (and you should), you'll find this snippet: "You hereby grant Ring and its licensees an unlimited, irrevocable, fee-free and royalty-free, perpetual, worldwide right to use, distribute, store, delete, translate, copy, modify, display, and create derivative works from such content that you share through our services." The company works in cooperation with hundreds of police forces to supply video on request, although the exact terms of this sharing are still unclear. Ring is undoubtedly a useful bit of kit, and can be a boon in crime detection, but the costs to privacy continues to worry many. **–CL**

New Consoles, New War

HERE WE GO AGAIN, Sony and Microsoft go head to head with new consoles. Microsoft is historically the underdog, while the PlayStation has an excellent track record. The PS2 dominated the original Xbox, the PS3 eventually outsold the Xbox 360, and the PS4 sold twice as many as the Xbox One. Will this round finally go to Microsoft? What's clear is that there isn't a huge technical gap between the machines. Both carry an eight-core Zen 2 processor and RDNA2 GPUs. Clock speeds are similar—Microsoft has opted for fixed rates, while Sony has gone with variable ones. Both have 16GB of GDDR6, and fast solid state storage. The Xbox does have a beefier GPU. Both boast of customization, Microsoft makes much of it storage system, and Sony says it has various "tricks" to close any performance gaps, and its storage bandwidth is (on paper) faster.

So, both are hugely capable gaming machines, and neither has an unequivocal lead. Yes, the Xbox has proved a few percentage points faster in early gaming tests in most modes, but it's hardly a convincing win. While advocates of both sides will no doubt claim superiority, this is a well-matched pair. The Xbox has Game Pass (a considerable plus), Quick Resume, excellent backward compatibility, but lacks exclusive games. The PS has more exclusive games, faster storage, better audio, and a haptic controller. There are some teething troubles, some TVs don't cooperate with the PS5 very well, and both have suffered bugs. The top models are both $499 too. Sony's digital edition (no optical drive) is $399, and has the same guts as its big brother. Microsoft's digital edition, the Xbox Series S, is $299, a useful saving, but you get a GPU with about half the power. It is far too early to say which one is selling better either, as both companies are selling as many as they can get to market. This year's sales will show the real story. **–CL**

Western Digital Marketing Woes

Earlier this year customers of Western Digital uncovered that some of its 5,400rpm drives were in fact 7,200 drives, thanks to some investigation using clever acoustic analysis. Yep, the drives were spinning faster than WD had claimed. The company has now renamed a series of Red Plus drives to reflect their actual speeds. Most of us might be pleased to have drives that are faster than we thought, but if you're building a big array where thermal and power profiles are important, it's not such a pleasing prospect. The move was all pure marketing. The drives may have been 7,200, but WD preferred to market them as "5,400 class" to preserve market distinction. **–CL**

Apple Cuts

If you sell through Apple's App Store the company takes a 30 percent share, a bone of contention with many developers, notably Epic Games, which got into a fight with Apple over in-game purchases in *Fortnite*. The game was suspended from the Apple and Google stores, and legal action ensued. Epic is one of a number of developers that have formed the Coalition for App Fairness. Apple has countered by lowering fees to 15 percent, but only if sales are below $1 million. Epic's CEO claimed that Apple was "hoping to remove enough critics that they can get away with their blockade on competition and 30% tax." This one is going to run and run, especially as the House of Representatives investigates anti-competitive practices. **–CL**

© RING

Jarred Walton

TECH TALK

The Race to 5nm

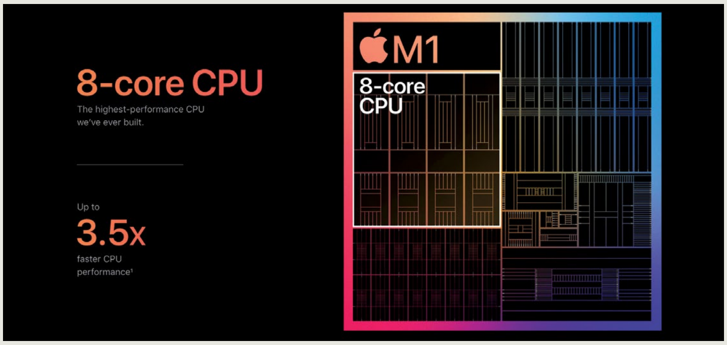
MOORE'S LAW MIGHT BE DEAD, or at least seriously slowing down, but progress hasn't stopped. 2019 saw AMD launch Ryzen 3000 CPUs and Radeon RX 5000 GPUs on TSMC's then cutting-edge N7 process, and 2020 brought us the Ryzen 5000 and Radeon RX 6000 chips on the same node. Nvidia opted for Samsung 8N for its RTX 30-series GPUs (and N7 for the datacenter GA100), while Intel still tries to get a handle on 10nm. The question now: Which company will be the first to release 5nm hardware?

If you want to count Apple, it already launched the first consumer 5nm chips built on TSMC's EUV-enhanced N5 node in October 2020. OK, maybe the A14 silicon doesn't count since it's not going into anything remotely PC. If that's your mindset, certainly the A14-derived M1 processor at the heart of the new MacBook line qualifies. Still, we want AMD and Nvidia—and maybe even Intel, if it outsources to TSMC—hardware manufactured on a 5nm node.

You can see in our tech preview for the year that we don't expect it to happen anytime soon. Zen 3 and RDNA2 arrived late in 2020, along with Ampere. Even though Apple has been using N5 for a few months now, it looks like 2021 PC hardware will remain primarily focused on 7nm (or maybe 6nm) lithography. There are other options as well: TSMC N7, N7P, and N6 are all in production, with the latter functioning as a potential bridge between DUV (Deep Ultraviolet) and EUV (Extreme Ultraviolet) lithography. But TSMC's N5 is set to use more EUV layers, maybe 20 or more.

Based on the current state of affairs, the safe bet for 5nm PC CPUs and GPUs is AMD. We know both RDNA3 and Zen 4 are in the works, and both are expected to use TSMC N5. However, don't count Nvidia out—especially after it went and acquired ARM Holdings for a heartstopping $40 billion. Subject to regulatory approval, sure, but Nvidia really wants its own CPU family, and ARM seems like the perfect fit.

There's also the question of whether Nvidia got a bit too comfortable in the GPU space with Ampere. The Radeon RX 6800 series doesn't clearly beat RTX 30-series GPUs, but it's arguably as close as AMD has come since the days of the HD 7970. AMD still has the console wins that tend to encourage game developers to leverage AMD features rather than focusing on Nvidia. Perhaps Team Green will fast-track an N5 design, to put AMD back in its place?



Apple technically already won the race to 5nm.

Alternatively, and hear me out, Nvidia could start pushing to make a competitive ARM-based chip for Windows. Nvidia was ready to dabble in x86-compatibility with Project Denver in 2013, which would have leveraged binary translation to enable x86 code to run on its ARM CPU cores. Intel put the kibosh on that with legal and licensing deals, but x86 is probably as vulnerable as its ever been right now.

It's not like PC users would need to suddenly migrate to ARM and some alternative OS, either. Windows on ARM continues to gain traction, and Apple has just waved a big middle finger at Intel and x86. Wouldn't that be ironic, if Apple was one of the driving impetuses for Microsoft shifting more resources from x86 to Windows on ARM? That's probably still many years away, but for the mobile market, the x86 exodus is well under way.

Even as mobile designs improve, there's still no getting away from desktop power. Nvidia has ambitions to displace x86 with ARM, but there will still be a place for desktops with chunky GPUs and CPUs. No matter how fast the next gen of smartphones and laptops become, zipping along on 5W to 20W SoCs, the easiest way to get more performance is to crank the power to 200-500W. With Mellanox under the corporate umbrella along with ARM, all-Nvidia servers and supercomputers are on the roadmap somewhere.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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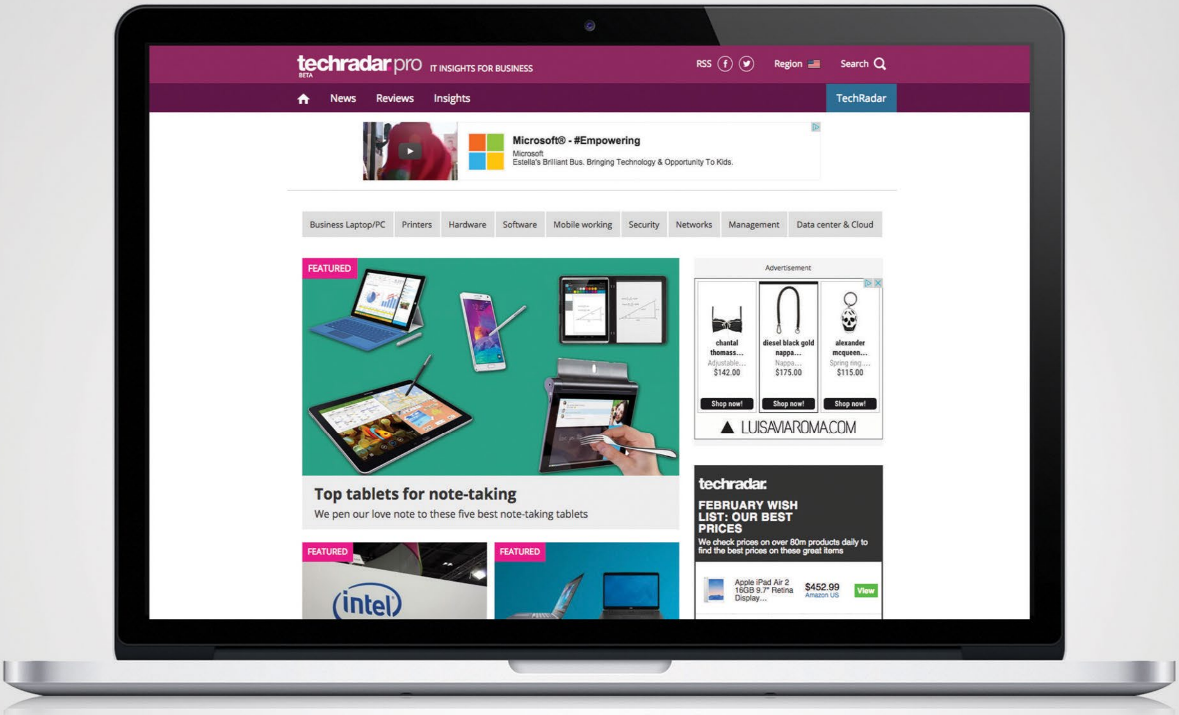
IT INSIGHTS FOR BUSINESS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THE LIST

MAXIMUM PC'S FAVORITE PERIPHERALS OF ALL TIME

8

LOGITECH G15 2006 Blue backlighting and a built-in LCD panel with macro support? The G15 was ahead of its time, but it does look truly dated.

7

CORSAIR VOID PRO 2017 Our resident staff writer was actually present at the Gamescom launch of this headset, and it has since proved to be an invaluable companion for daily online games.

6

STEELSERIES H5V3 2013 SteelSeries has always produced solid peripherals, and the H5v3 was no exception. Leather padding, a double-braided cable, and great portability set this headset apart from the crowd.

5

LOGITECH G502 LIGHTSPEED 2019 It might be expensive, and more recent than other entries on this list, but the G502 Lightspeed is a simply sublime mouse that will take some beating.

4

MICROSOFT SIDEWINDER X5 2008 Remember when Microsoft made gaming mice? *Maximum PC* remembers. It might've looked weird, but the 2,000 DPI optical sensor made the X5 a great purchase at the time.

3

RAZER BLACKWIDOW ULTIMATE 2016 The 2016 "Ultimate" model came with Razer's signature green lighting and tactile orange switches, which were near-silent: perfect for late-night gaming.

2

ANTEC SOUNDSCIENCE ROCKUS 3D 2.1 SPEAKERS 2010 This piece of kit was a high-quality three-piece desktop speaker system that was capable of rich, room-filling sound thanks to its forward-firing subwoofer and the dual satellite speakers.

1

LOGITECH C920 HD PRO 2015 Can you tell that we like Logitech's stuff? This 1080p webcam is still kicking around, because it was perfect when it came out and it's perfect now, even with the weird "logi" logo.

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DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> CPU Temps
> Is Free Software Safe?
> Choose Headphones

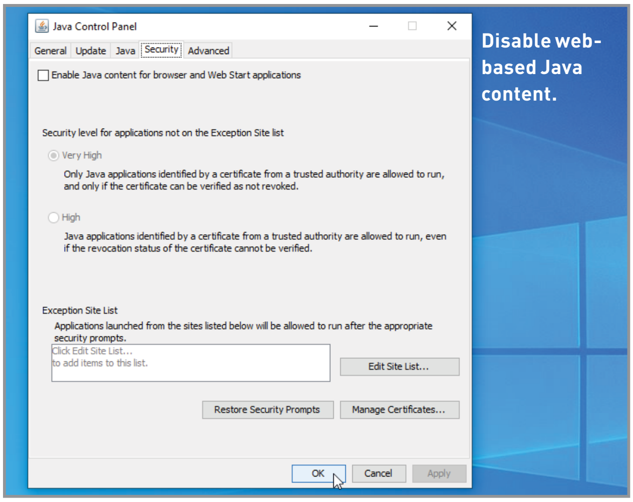
CPU Temperature Fluctuation

I've been using Open Hardware Monitor to control my CPU fan. This was the only app I could find that controlled it. I have an Asus ROG Strix B450-F motherboard, AMD Ryzen 5 3600 overclocked to 4,150 MHz, and the stock AMD CPU cooler. I tried to control the fan from the motherboard, but it didn't work. I also have two NVMe SSDs, two SATA SSDs, ODD, three 140mm case fans, and a 120mm case fan, all fans blowing inward, all housed in a Corsair 110R case.

My question is why does the temperature in the processor vary over a six-hour period when the voltage, fan speed, and room temp don't change? Do I need a better cooler? Check out the six-hour graph I have attached, and you'll see what I mean. **–Papa Homey**

THE DOCTOR RESPONDS: Your CPU is never completely idle, so it's unsurprising that the temperature fluctuates as the CPU load changes—even if you've left it to its own devices. Background processes continue to run, while even light use of your PC to browse web pages or edit a text file will have some effect. All you need to do is open Task Manager to the "Processes" tab, then click on the "CPU" tab to see the constant ebb and flow in CPU usage, which will correlate to temperature changes.

Looking closely at your graph suggests that everything appears normal—your CPU temperature tends to fluctuate between 55-70C, which is well below the "safe" figure of 80C. Improving your cooling would help reduce this figure further, and the Doc is intrigued as to why all your case fans are drawing air into the case—you should ideally have the fans at the rear drawing colder air in, while fans at the front blow the hot air out. So, if you're not currently doing this, a simple rearrangement of your current setup should help drive those CPU temperatures down further—even when overclocked, your CPU should be around 40C while idling.



Java Control Panel

☐ Enable Java content for browser and Web Start applications

Security level for applications not on the Exception Site list

● Very High

Only Java applications identified by a certificate from a trusted authority are allowed to run, and only if the certificate can be verified as not revoked.

○ High

Java applications identified by a certificate from a trusted authority are allowed to run, even if the revocation status of the certificate cannot be verified.

Exception Site List

Applications launched from the sites listed below will be allowed to run after the appropriate security prompts.

Click Edit Site List...
to add items to this list.

Disable web-based Java content.

Is Free Software Safe?

Two questions if I may: First, I keep getting these notices that Java needs to be updated. Is there a program out there that will list/show which programs I have on my computer that require/are using Java to run?

Second, the May 2020 issue of *Maximum PC* had an article on free software. Some of them look interesting, but I've always been concerned as to whether free software is safe to use. Do I have a reason to be concerned? Along those lines, I saw that you mentioned Malwarebytes. What is the difference between the free version and the version you purchase? **–R.T.**

THE DOCTOR RESPONDS: Sadly, there's no way to find out which applications require Java on your PC, short of generating a list of apps installed (use "Settings → Apps → Apps & Features") and then Googling each one to see whether Java is listed among its system requirements. Or you could simply remove all versions of Java from your PC using the Uninstall Java Versions tools (www.java.com/en/download/uninstalltool.jsp) and wait to see which programs complain when they can't find it (in which case, just download it again from www.java.com).

If the frequency of updates annoys you, type "configure java" into the Search box to open the Java Control Panel—use the "Update" tab to stop automatic updates or reduce the frequency of checks to monthly, but if you do so, we also recommend switching to the "Security" tab and unticking "Enable Java

© MICROSOFT

↘ submit your questions to: doctor@maximumpc.com content for browser and Web Start applications" to close a potential security loophole.

Moving on to your second question, if the program gets a thumbs up from the mag, you can be sure we've investigated it thoroughly, scanned it with our own security software, and installed it on our computer. These days, there's usually a free program that offers most—if not all—the functionality of paid-for products. The Doc relies on lots of free apps on a day-to-day basis, whether it's Paint.NET for photo editing, Handbrake for video encoding, or Bitwarden for password management. We're particular fans of open-source programs, which make their code available for anyone to view, audit, or even fork off into a separate project. Such transparency makes them more trustworthy.

That's not a universal guarantee, of course—there is plenty of dubious software out there, both free and paid-for, so the usual caveats apply. Start by reading up about an app that interests you—Google its name with keywords such as "review" and "malware" to gauge its reputation. If you decide to download it, make sure you do so from the author's website or a trusted mirror such as MajorGeeks.com. Also, be sure to scan the downloaded file for malware—your anti-malware software should do this automatically, but there's no harm in right-clicking it and choosing the "Scan" option to confirm.

Lastly, Malwarebytes Anti-Malware is a great secondary layer of protection to run alongside your existing anti-malware program. The major difference between the free and paid-for versions is that the paid-for version offers four real-time protection components that cover malware, ransomware, exploits, and web (dodgy websites)— all without interfering with any existing anti-malware software. The free version will scan and remove malware threats, but you'll need to remember to run manual scans regularly.

USB Cable Replacement

Thank you for keeping up the magazine in these trying times. You guys are awesome! I had my joystick plugged into the USB 3.0 plug, in front of my machine. As I walked by, I bent and cracked the little plastic thing inside. So, I opened the case, removed the cable that plugs into the motherboard to find out that it split into two USB 3.0 connectors plugged into the front of my case. I called the manufacturer to find out they don't make them anymore, and they hung up on me. The cable is 40cm from tip to tip. Can you refer me to someone who makes them, as I'm having trouble locating one? **–D Dominguez**

THE DOCTOR RESPONDS: This question became a heck of a lot easier to answer because you've thoughtfully provided a series of photos of the defective part in question, which revealed the key connectors we needed to identify in order to source a generic replacement. At one end is a 20-pin female motherboard connector, while at the other are two female USB-A ports designed to slot into place in the case chassis. Sadly, you forgot to list the case make and model, which made things tricker.

The two female USB-A ports aren't molded in plastic, which narrows the available options down. In the end, we resorted to a Google Images search for "20-pin connector to USB port" to perform a visual inspection of potential matches. This led us to the closest match we could find, a 1.6-foot cable from Toptekits ($11.99, www.amazon.com/dp/B010NBLRHK). The biggest issue will be the Toptekits screw mount, which you may need to shave to fit your case.

If it's impossible to fit, you could try an alternative approach if you have a spare external 5.25-inch drive bay—fosa's 5.25-inch multifunction reader includes three USB 3.0 ports and one USB-C port for under $19 (www.amazon.com/dp/B07CK17QSY/), and connects to the same USB socket on your motherboard as the original cable.

© AUDIO TECHNICA

Audio Technica is a well-regarded headphones manufacturer.

Choosing Headphones

Dear Doc, there are so many headphones! I'd like to purchase a sub-$200 pair of cans. It should have Bluetooth and ideally a wired 3.5mm jack, plus perhaps a removable or retractable microphone. Great sound goes without saying: I'm not a super-audiophile, but I would like a pair that will last me and be able to be used on both my PC to game with friends as well as to listen to some music in comfort.

There's so much choice, how do you begin to sort through them all? I'm starting from the beginning and am just so lost. **–Archimedes Inferno**

THE DOCTOR RESPONDS: There's no substitute for piggybacking on other people's experiences—namely reviews—but while user reviews are important, you should always remember that many may be fake, although these tend to be easy to spot given they're so effusive with their praise. With that in mind, professional reviews from reputable magazines and websites like *What Hi-Fi* (www.whathifi.com/products/headphones) are crucial. These also help steer you away from one of the many dozens of cheap brands towards more established, reputable names.

Beyond this, looking at your wish list, one crucial factor stands out: Longevity, which again highlights the importance of steering towards a well-known brand. This will push the price up but should still give you ample room within your $200 budget. The upside is that you'll gain access to a website with meaningful support, including forums where you can get a feel for a pair's reputation from other users—one thing to remember is that you'll find plenty of problems and complaints that may skew your feelings, but unless lots of people are reporting the same unresolvable problems, keep those gripes in perspective.

The other consideration you mention is comfort. Some people are fine with earbuds, whereas the Doc prefers larger cans that can physically block out the noise, while sitting comfortably over rather than inside the ears. That said, this type can grow uncomfortably hot with prolonged use, so consider how long you'd want to listen with them in a single sitting.

Finally, some other considerations: If you're opting for Bluetooth, choose Bluetooth 4.2 or later, and if audio quality is important, make sure it supports the higher-quality aptX (www.aptx.com) codec. Battery life isn't as important if you're mostly playing games, where you've got access to an easy charge, but you do want something that won't need constant recharging, so aim for 10 hours as a minimum.

Finally, if you're still struggling to start your search, visit a website like Choosist (www.choosist.com/us/headphones/start) where you can input your budget to throw up a list of candidates. We stuck in your requirements, and Choosist suggested four models, including Audio Technica's ATH-SR5BT for $150. The Doc's owned a pair of wired Audio Technica ATH-ES7 cans for nine years, so it's a brand he recommends. ⏻

TECH PRE

THE MAXIMUM PC TEAM A COMING YEAR HAS IN STOR

IT FEELS LIKE an old and tired mantra at this point, but it's fair to say that 2020 was an awful and very challenging year. It's shown us just how dependent we are on that humble transistor. Life has changed, for better or worse, and the world we once knew likely won't exist in the same way it did when this pandemic ends. If the science comes true, and as population sizes swell, diseases like this will likely become far more commonplace. And with it there'll no doubt be an even greater shift in how we work, how we enjoy our spare time, and how we connect with our loved ones.

We're seeing this change happen already: More of us now than ever work from home, and the majority are keen to see that trend continue even after this period in history ends, at least on a flexible basis. In fact, although economies have faltered and gone into sharp recessions across the globe, perhaps unsurprisingly, the one area that hasn't been negatively impacted by this colossal moment in time is the tech industry. If anything it's boomed, as more of us have demanded faster processors, better connectivity, and new PCs, and because of that supply can't keep up with demand.

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VIEW 2021

ND CO. PREDICT WHAT THE
RE FOR THE WORLD OF TECH

The technologies that launched this year have been nothing if not impressive. We've seen new GPUs from AMD and Nvidia that have begun to really challenge the feasibility of 4K gaming; processor leaps that have disrupted long-time industry kings; more impressive monitor tech at far better prices; and an arsenal of new ergonomically designed peripherals—and even more have made their way into the design stages already.

At any other time in history, these launches would've been considered legendary. We've been absolutely spoiled with some incredible hardware over the last few months. Yet as the madness that is 2020 has now come to a close, this is truly only the beginning. As always, new trends, demands, and repercussions in innovation and design take time to make it to market, and the effects of COVID-19 on the industry and on the PC enthusiast community as a whole will only begin to be really felt later this year.

So what is coming? What can we expect? And what tech are we likely to see pop into existence? Well we've got the whole gang back together to give you the very best lowdown on the future tech of 2021.

VIPER
DOMINATOR
DOMINATOR

THE CPUS OF TOMORROW

INTEL VS AMD, THE BATTLE CONTINUES

2020 ended with a bang on the CPU front, with AMD's Zen 3 architecture claiming the overall CPU crown. Looking forward to 2021, Intel hopes to reclaim some of its lost glory, but AMD isn't resting on its laurels either.

After a busy 2020, AMD doesn't have plans for a completely new architecture this year. Zen 4 is in the works, but it's slated for 2022—it will be made using TSMC's N5 5nm lithography, likely with DDR5 and PCIe Gen5 support, and a new socket. Considering that Zen 3 just launched for desktops at the end of 2020, most of AMD's 2021 plans will involve rolling out Zen 3 across the rest of the portfolio. That means everything from mobile chips to servers, with additional Ryzen desktop SKUs as needed.

On the server front, AMD's Milan chips are expected to fill the same niche as the existing Zen 2 Rome chips, and will drop into existing motherboards. They'll top out at 64-core/128-thread versions, but instead of Zen 2 compute chiplets, they'll be upgraded to Zen 3 chiplets that have a unified 32MB L3 cache and a single core complex, plus all the other architectural enhancements. Naturally, we'll see the same designs show up in Threadripper 5000 variants for HEDT builds. A 32-core/64-thread Threadripper 5970X seems a given, and a 64-core 5990X may or may not see the light of day.

At the other end of the spectrum, laptops are due to get not just one but two potential upgrades this year. Cezanne is slated to use an eight-core Zen 3 CPU paired with a Vega 7 GPU, all in a monolithic die. Frankly, we're a bit tired of seeing the Vega GPUs as the only current option in AMD integrated graphics. Which is why AMD also has Van Gogh in the works—except that will apparently pair Zen 2 CPU cores with a Navi 2x GPU, according to the latest roadmap leaks. It seems likely that Van Gogh will go after the 7.5-18W range, meaning it's targeting Intel's Tiger Lake, and will probably have a four-core/eight-thread CPU. As for the Navi 2x graphics, it's difficult to imagine AMD cramming ray tracing into integrated graphics, so it may be more of a Navi 1x design in a lot of respects.

Flipping over to Intel, the company is looking to strike back at AMD's Ryzen 5000 chips with Rocket Lake, which will have backported Cypress Cove CPU cores—basically, those are Ice Lake's Sunny Cove cores, but on 14nm+++ instead of 10nm. It's a bit of a mess, but Intel claims it will deliver more than a 10 percent IPC (Instructions Per Cycle) increase relative to the current Comet Lake, and could still clock as high as 5GHz. Rocket Lake will also support PCIe Gen4 and feature Intel Xe integrated graphics. The big problem is that it will top out at eight CPU cores, which is a step back from the current 10-core i9-10900K. In short, it won't be able to touch AMD's 5900X/5950X multi-threaded performance.

Intel has a second completely new CPU architecture slated for 2021 as well—Alder Lake. This is where things really get interesting. Alder Lake will be a hybrid CPU design, sporting up to eight Golden Cove high-performance CPU cores, and eight Gracemont low-power cores. Unlike Rocket Lake, Alder Lake will be manufactured using Intel's SuperFIN 10nm node, making it the first 10nm desktop CPU from the company. It will also move to a new LGA1700 socket, with DDR5 memory support, and will continue to leverage Xe Graphics on the GPU front. It sounds impressive, but the hybrid design could make things messy on Windows, which isn't that great at figuring out how to balance loads across cores of potentially wildly different performance.

Finally, Intel also has Tiger Lake-H CPUs slated to launch for laptops in 2021. These will pack up to eight Willow Cove CPU cores and should offer a substantial boost to performance. It's interesting that Intel hasn't mentioned any plans to release Tiger Lake on the desktop—normally high-end laptops use the same chips found in desktops, just limited to lower power levels. Maybe Intel thinks that Alder Lake already covers this sector, but then why not just do Alder Lake for laptops as well? Either way, 2021 is shaping up to be very interesting in the CPU sector.

BREAKING GRAPHICAL LIMITS

ITERATIONAL CHANGES AND MORE MID-RANGE COMPETITION?

Last year was pretty slow-going on the GPU front, right up until September, when Nvidia blew open the doors with its new Ampere architecture and RTX 30-series graphics cards. AMD followed suit with the RX 6800 series in November and December. Considering 2020 ended with an explosion of GPU launches, we don't anticipate anything radically new for 2021. Which isn't to say there won't be a ton of new GPUs coming out; they'll just be more iterative and will go after the mainstream and budget markets,

AMD Ryzen 9 5900X
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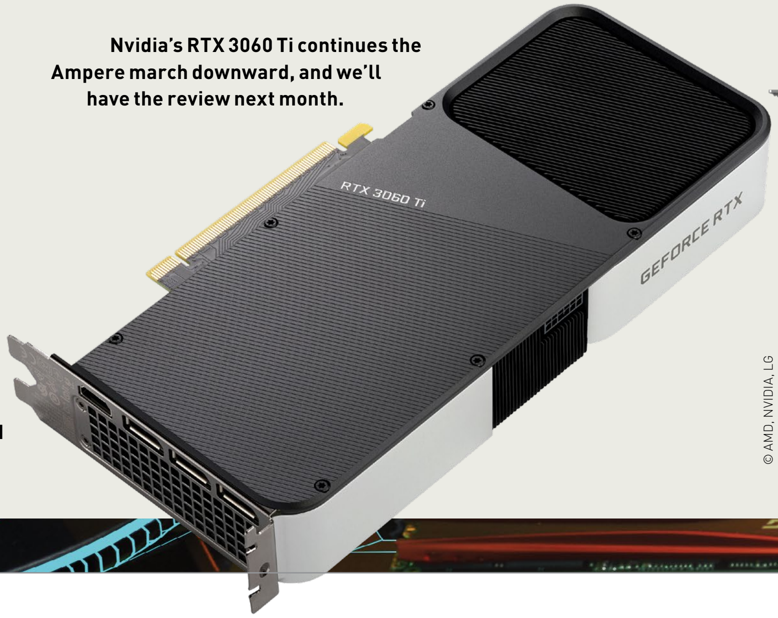
DIFFUSED IN USA
DIFFUSED IN TAIWAN
MADE IN CHINA
© 2020 AMD

AMD's Ryzen 9 5900X is fresh out of the gates, packing awesome single-threaded and multi-threaded performance. AMD doesn't plan on replacing it in 2021.



Nvidia's RTX 3060 Ti continues the Ampere march downward, and we'll have the review next month.

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rather than going out and delivering new levels of performance. Probably, anyway.

AMD's Radeon RX 6800 series debuts in this issue (see page 74), bringing with it the new RDNA2 architecture and a whopping 128MB Infinity Cache. Performance in traditional games is right up with Nvidia's best, but turn on ray tracing and things aren't looking as promising. So where does AMD go from here?

For 2021, we expect RDNA2 to trickle down to lower tier products, with the RX 6800 XT and the RX 6900 XT (coming next issue) staying at the top of the product stack. We expect to see RX 6700 XT and RX 6500 XT models at the very least, probably RX 6700 and RX 6500 as well. But scaling RDNA2 down from Navi 21 presents some interesting challenges.

AMD talked a lot about its Infinity Cache for the biggest chip, but there's pretty much no way that AMD can put a 128MB cache in the mainstream and budget variants. We've already seen that the 128MB cache doesn't benefit 4K gaming as much as 1440p and 1080p, but will a 64MB or 32MB Infinity Cache still be sufficient? We'll likely find out later this year.

Navi 22 is the rumored mainstream offering, with 40 CUs and a 64MB Infinity Cache. It might end up with 12GB of memory, or potentially 8GB. It will be a mainstream part, going after the $300-$450 market segment (give or take). Below that is Navi 23, the pseudo-budget part that will probably start at around $200, with a 32MB Infinity Cache. There may even be a Navi 24 chip, but it's difficult to imagine RDNA2's full feature set (including ray tracing) scaled down that far. Then again, Xbox Series S exists, so we might get a PC equivalent.

On the Nvidia front, right now the lowest tier Ampere part is the RTX 3070, but it will be joined by the RTX 3060 Ti. It's the same GA104 chip, with the same 8GB of GDDR6 14Gbps memory; it just trims the chip down to 4,864 CUDA cores and 38 SMs (compared to 46 SMs on the 3070). That should mean about 15 percent less performance, with a price of $399. Compared to the outgoing RTX 2060 Super, it should be a healthy step up in performance—Nvidia claims it will be five to 10 percent faster than the RTX 2080 Super, and around 40 percent faster than the 2060 Super.

Where there's an RTX 3060 Ti, there's bound to be an RTX 3060. That will use a new GA106 chip, with 6GB of GDDR6 memory and a rumored 30 SMs (3,840 shader cores). GA106 is also rumored to show up in RTX 3050 Ti, with the same 6GB memory and 26 or 28 SMs. Below that there's talk of a GA107 with 18 or 20 SMs and 4GB of GDDR6. It's difficult to imagine such a card getting acceptable ray-tracing performance, but maybe for 1080p with DLSS?

Nvidia is also likely to have beefed up RTX 3070 Ti and RTX 3080 Ti models coming in the near future. After all, AMD is winning on the VRAM front right now, but doubling to 16GB GDDR6 on the 3070 Ti and 20GB of GDDR6X on the 3080 Ti would solve that problem. Considering the 6900 XT will likely close the gap with the RTX 3080, we anticipate a $900-$1,000 price on the 3080 Ti.

There's also an outside chance that Nvidia does a refresh of Ampere later in the year, shifting to TSMC's superior N7 or N7P node. Ampere GA100 is already on N7, so it may not be that difficult. TSMC delivers higher density and efficiency as well, and stranger things have happened. More likely, the next big move from Nvidia will be Hopper in 2022, built on TSMC N5 with EUV lithography. It will go up against AMD's RDNA3.

PUSHING PIXELS PER INCH

SAY GOODBYE TO BEZELS AND HELLO TO AFFORDABLE HIGH-REFRESH 4K

■ Five years ago, the future of PC displays was almost certainly OLED. Now we're not sure that's ever going to happen. Yes, OLED technology has a small foothold in the laptop PC segment. but as yet, OLED desktop monitors are virtually non-existent.

For 2021, that isn't going to change. In fact, it's very likely that the next big thing in PC displays will be microLED, not OLED. But, again, microLED is far from imminent. So what will change in 2021 when it comes to PC displays?

In strict technological terms, not much. There will be little to nothing that's substantially new. Instead, you can expect to see existing technology become cheaper and improve incrementally.

As for the specifics, don't expect any huge revolutions in the actual LCD panels that go into desktop and laptop displays. Marginal improvements in areas like contrast and pixel response are reasonable, but not major step changes. To put this into context, over the past 10 years IPS-type panels have seen static contrast improve from around 1,000:1 to 1,300:1, and native pixel response, as opposed to overdriven response, improve from around 25ms to something closer to 10ms.

LCD technology tends to improve only gradually. That notion extends to screen resolution. The last big leap was the jump to 4K or UHD and 3,840 x 2,160 pixels. While that makes for a huge number of pixels—over 8 million—it doesn't necessarily translate into a true high-DPI display, at least in desktop terms.

AMD's RX 6800 just came out, and represents the current bottom of RDNA2, but it will be joined by mainstream and budget RDNA2 alternatives later this year.

Slim bezels along with mini-LED and more affordable 4K high refresh are among the highlights for screens in 2021.

A 27-inch 4K panel, for instance, translates into 163 pixels per inch. While that's decent, a true high-DPI display probably requires something closer to 200 pixels per inch, albeit assumptions regarding viewing distance are inevitably involved.

Obviously, larger displays of 32 inches or more only transport the viewer even further away from that high-DPI experience. The solution for those seeking a high-DPI experience on the PC is more pixels in general, and 8K more specifically. That's 7,680 x 4,320 pixels. At 32 inches, 8K works out as 190 pixels per inch. However, while the TV market is beginning to see the first examples of what you might call non-exotic if not truly affordable 8K screens, 8K remains a rare beast in PC monitors.

While 8K is not going to be the norm anytime soon, a few more 8K-capable monitors should appear next year, as the product road maps from the major panel makers proves. Those road maps provide cause for cautious optimism in other areas, too.

Take LG Display, the inventor of the IPS panel and one of the biggest suppliers to monitor makers. For 2021, LG has a new 31.5-inch 8K IPS panel. It's a fairly conventional panel in other regards, with a peak brightness of 400cd/m2. But it will hopefully be the basis of a new series of slightly more affordable 8K monitors.

LG is also planning a new generation of panels with mini-LED backlights. These go beyond existing "full array" backlights used to achieve local dimming in HDR monitors by dramatically increasing the number of dimming zones. Peak brightness is also expected to jump up to as much as 1,250 cd/m2. Those two developments should see the arrival of the first PC monitors that truly deserve to be sold as HDR capable.

One early example from LG is a 31.5-inch IPS panel that should be available to monitor manufacturers in early 2021. It has slim bezel on all sides, packs 3,840 x 2,160 pixels and a backlight with more than 2,000 mini-LED zones, and HDR 1,000 certification.

Other interesting panels in LG's lineup for 2021 include another more affordable 31.5-inch 4K panel, this time with 144Hz refresh support but a more conventional full-array backlight. More broadly, LG will be releasing a new generation of what it calls "Oxide" panels with super-slim sub-3mm bezels on all four edges of the panel. Other LG panels to look out for include a 40-inch IPS model with 5,120 x 2,160 pixels, and a number of 240Hz IPS panels.

Meanwhile, one of LG's cut-price competitors has a few interesting panels in the works. AU's upcoming 27-inch panel combines its take on IPS (known as AHVA) with ultra-slim bezels, 4K resolution, and 95 percent of the DCI-P3 color space.

Along with a number of high-refresh 1080p and 1440p AHVA panels, arguably one of AU's more exciting panels is a 32-inch AHVA 4K model with 144Hz refresh, 10-bit color, slim bezels, and a 1,152-zone mini-LED backlight capable of 1,400 cd/m2 peak brightness. Just as exciting for PC enthusiasts on a tighter budget, AU has a new 32-inch 144Hz panel with a more conventional (and cheaper) edge-lit panel coming too.

All told, mini-LED, more affordable high-refresh and 4K panels look to be the major trends for next year, from the small band of manufacturers who make the panels that go into monitors from a wide range of brands. In other words, a reasonably affordable 32-inch, 144Hz 4K monitor with IPS-quality visuals might just be a thing in 2021. Meanwhile, an 8K monitor priced nearer $1,500 than $5,000 could be on the cards. Granted, neither of those options is as dramatic as a wholesale shift to microLED. But should they come to pass, they would still be very welcome developments.

STORAGE IN 2021

PCIE 4.0 GOES MAINSTREAM, AND INTEL'S OPTANE IS REBORN

■ Speaking of technological revolutions that never happened, both Intel's Optane and Samsung's Z-NAND have been duds since their inception, at least in contrast to the promise they suggested at launch. Neither of these new alternatives to NAND flash memory have become the technology of choice for persistent solid-state memory. That doesn't look likely to change in 2021.

Samsung has gone conspicuously quiet concerning Z-NAND. As for Intel, its Optane technology has seemingly been at least delayed by the breakdown in the relationship with Intel's technology partner Micron. However, the second generation of Optane SSDs, codenamed Alder Stream, should appear in 2021. Specifics are pretty hard to come by, but once again latency and IOPS performance should be the main highlights.

Intel has spoken in vague terms about "many millions" of IOPS performance. If that turns out to be true, Optane 2.0 will set new standards for random-access performance. However, we aren't expecting the second coming of Optane to deliver that performance for a price anywhere near traditional NAND flash drives, so it's likely to remain a niche and pricey storage option.

Back in the mainstream, the big news for 2021 will be the wider adoption of PCI Express 4.0 interfaces on otherwise fairly

V-NAND SSD
980 PRO
PCIe 4.0 NVMe M.2
SAMSUNG
www.samsung.com/ssd
SAMSUNG ELECTRONICS CO., LTD.
500GB

Samsung's 980 Pro is among the new breed of super-fast PICe 4.0 SSDs.

Next-gen games console tech is set to accelerate PC storage performance in 2021.

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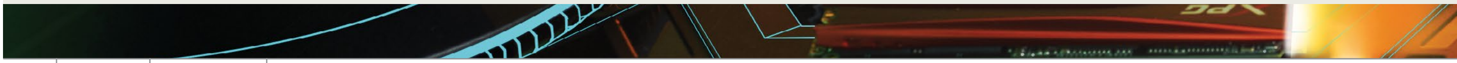


conventional NAND drives. Of course, PCI Express 4.0 is not new per se for 2021. Compatible drives, motherboards, and CPUs were already available in 2019, but only on AMD platforms. For 2021, Intel will belatedly join the party with its upcoming Rocket Lake chips, which will bring native PCIe 4.0 support.

As for Intel-flavored motherboard support, the good news is that Rocket Lake is backwards compatible with existing Intel 400-series chipsets. Many existing Intel 400-based motherboards may be able to support PCIe 4.0 courtesy of a Rocket Lake CPU and a BIOS update. However, we would advise caution and refer to the board manufacturer before jumping to any conclusions.

In any case, PCIe 4.0 essentially doubles raw bandwidth over PCIe 3.0. As we've seen with the new Samsung 980 Pro, it can translate into pretty epic peak performance. On our testbed, the 980 Pro cranked out 7GB/s of read performance and 5GB/s of write, though the increase in random-access performance was slightly less dramatic. Regardless, PCIe 4.0 should become the norm for new PCs in 2021.

THE CONSOLE CONNECTION

One of the many highlights of the two new games consoles from Microsoft is a new approach to storage and indeed a greater focus on storage performance. Happily, the technologies involved are going to spill over to the PC.

Most notable is Microsoft's DirectStorage, a member of the broader DirectX API. According to Microsoft, even with super-fast PC hardware and a modern NVMe SSD, games using the existing APIs are unable to fully saturate the IO pipeline leaving precious bandwidth on the table.

The specifics of DirectStorage are complex. But the 10,000ft overview involves measures such as combining what were once thousands of sequential IO requests into batched, many-at-a-time parallel IO requests.

Existing storage APIs also incur a lot of "extra steps" between an application making an IO request and the request being fulfilled by the storage device, resulting in unnecessary request overhead. With a supported NVMe drive and properly configured PC, DirectStorage will be able to detect up front that these extra steps are not required and skip all the unnecessary checks/operations, making every IO request cheaper to fulfill.

Admittedly, DirectStorage and its companion technologies are aimed primarily at improving gaming performance. But it may also have wider implications for PC storage performance too.

THE WORLD OF COOLING

CHILLING THE FUTURE WITH NANO-COOLANT AND PELTIER EFFECTS

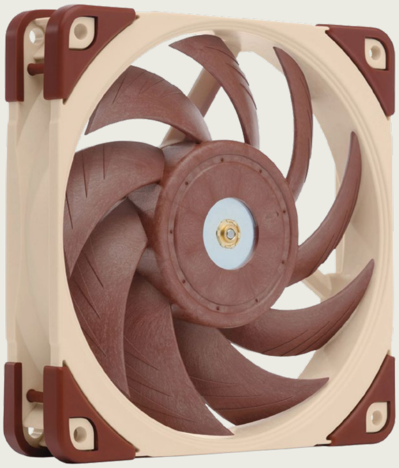
■ PC cooling is in a bit of a weird place at the moment. Processors are getting hotter, it's an observable fact. Whether you're looking at Intel or AMD, the race for faster chips is leading to the generation of more heat. You can see this in Intel's latest design push with its 10,000-series processors. The larger die and socket size, and the thinner IHS help dissipate heat more efficiently—it's happening because of that increased heat generated by higher performance and more voltage. The same is true of AMD: Team Red has a slight advantage, as its mainstream consumer processors are larger than Intel's, and the IHS has almost always been soldered on, but we're still seeing temps creep up in the mid-to-high 50s and 60s at idle, with a solid 240mm AIO cooler. The world of graphics has followed a similar pattern, with both Nvidia's latest RTX 3000-series and AMD's Radeon RX 6000-series cards featuring more complex fan designs and beefier two and a half slot coolers to help dissipate the excess heat generated by the introduction of ray tracing and denser GPU cores.

We're starting to see this spill over into the world of cooling design as well. In the custom loop world, EKWB has just debuted its EK-QuantumX Delta TEC water block. This is a very unique style of Intel CPU block, more aimed at the high-end overclocker than the average person, but what it does is provide sub-ambient temperatures across the processor by taking advantage of a Peltier/thermoelectric cooler plate.

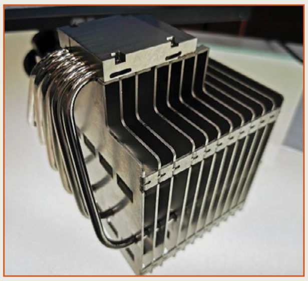
SUB-AMBIENT COOLING

Think of a TEC or Peltier device as a form of solid state refrigeration. In essence it has a single piece of thermally conductive material in it. When a current flows through that material, it pulls thermal energy from one end of the material to the other end. What that does is cool the side that's losing that thermal energy, and pushes the excess heat to the other end, which is typically attached to a heatsink operating at ambient room temperatures.

TEC style solutions could become the standard for the future of processor performance.



A chromax variant of this epic fan would be much appreciated.



Noctua's fanless heatsink is a monster tower, with an impressive aluminum fin design.

NANO COOLANT AIOs

We've spent a lot of time working with Mayhems over the last few months on its XTR coolant. It still continues to impress us as far as coolant goes, but it's fair to say that it is very niche, especially for the mass market.

However, perhaps it might not be. For those that don't know, Mayhems actually produces a lot of the coolant for Corsair's custom liquid-cooling product line, a market that has interestingly exploded over the last year alone (it seems that folks like tinkering with their rigs and building liquid-cooled loops in lockdown).

But could XTR make its way into the realms of AIOs? We can't say for sure, but tests have been carried out in Corsair's Hydro series AIOs with the custom coolant, and there's reportedly a marked improvement over the glycol-based solution that's used by most manufacturers.

XTR was actually designed and developed with small radiator cooling in mind. In these scenarios maximum thermal efficiency is far easier to reach than within a fully custom loop, and so moving heat away to the radiators as fast as possible is far more important. That said, AIOs provide some significant hurdles that need to be overcome if we're to see this transition occur. For one, AIOs use smaller pumps than fully custom-built loops, which could be a hindrance for XTR's tiny particles, and secondly it needs to be self-maintaining over many years, and not degrade. Testing is underway, but unsurprisingly it will take a while to see the results of that come to fruition. So it may be later in this decade that we see a transition over to more efficient AIOs, with superior coolant as well.

In EKWB's case, unlike its usual waterblocks, Only the TEC itself makes contact with the processor directly. When installed in a loop, the coolant cools the heatsink attached to the TEC, pulling that excess heat away from the TEC and into the radiators. It's worth pointing out that this is not really an efficient way of cooling something. It uses additional power to perform this process, but it will ensure sub-ambient temps for the processor in question.

Now immediately there's a few hurdles to overcome with this. Perhaps the biggest one is condensation. Because it's operating at sub-ambient temperatures, any moisture in the air is likely to condense on the processor. EK suggests that it's got around this by using an advanced form of integrated insulation that isolates all of the cold surfaces from any environmental conditions internally in the rig. On top of that, it's partnered with intel to develop specific software and firmware known as "Cryo Cooling Technology" to continually monitor and adapt the conditions to minimize any potential risk created through the use of the TEC.

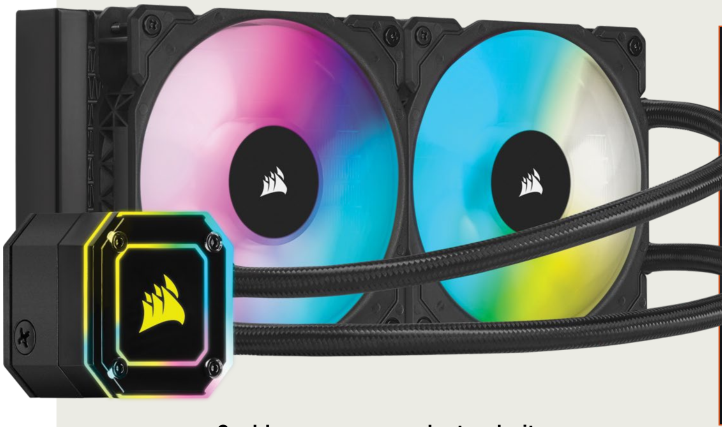
If this works well, it could be an incredible step towards sub-ambient cooling being a regular addition to high-end processors, and it's likely we'll see more of this tech from far more companies, with it even being integrated into the likes of AIO liquid coolers later in 2021 and 2022. Additionally, as it becomes more popular, its costs should decrease. As our power-draw requirements have plummeted over the years, there's plenty of headroom in a lot of systems to use that excess power to siphon off additional heat generated by the processors, both in GPUs and in CPUs.

One thing worth noting is that EK's QuantumX Delta TEC currently costs $417 for the block alone. But this is an exciting next step: If the technology becomes prominent, both Intel and AMD could start pushing their high-end chips to operate at expanded frequencies when paired with a TEC-like device such as this. We could see aftermarket variants pop up from the likes of Cooler Master, Corsair, and more, if it proves very successful.

CASE FANS

As for fans, things are more unknown, perhaps unsurprisingly given the nature of the market. Rumors abound that Noctua might finally be releasing a Chromax variant of its NF-F12 successor, the NF-A12. The A12, debuting back in 2019, featured a potent new motor design, and had tolerances of less than 0.5mm between the blades and the outside edge. Reconfiguring the materials to take advantage of the more common black color has taken time, but it's likely to arrive this year. Its 2.34mmH2O static pressure and max airflow of 102,1m3/h at 22.6dB(A) make it one of the most powerful radiator fans on the market.

Another interesting product coming from the big beige company is its Fanless CPU cooler. Originally slated for launch in 2020, this behemoth of a passive aluminum air-tower (weighing in at 3.3lbs) is capable of cooling processors with a TDP of up to 120W guaranteed. However, in more confined environments, and with the assistance of a few internal case fans, that figure can rise to a staggering 180W of total heat output (even in both configurations, that's enough potency to cool an AMD Ryzen 9 5950X, or Intel's Core i9-10900K). The last we saw of this thing was at Computex 2019, where it managed to keep an Intel Core i9-9900K at 94C, while running a fully loaded instance of Prime95,



Could we see nano-coolant make its way into Corsair's next-gen coolers?

HP's latest VR headset looks set to blow Oculus and HTC out of the water.

© CORSAIR, HP, DUCKY, RAZER

all day long, in Taiwan's very balmy climate. Expect this to launch some time in Q1 2021.

Corsair's ML120 Pros, revolutionary when first launched, are getting long in the tooth. With the launch of the most recent Capellix line of coolers, these AIOs came with a brand new fan iteration in the form of the ML RGB series. These are only minor updates, but currently the fans can only be bought included with the AIO itself, so expect to see these come to market around June.

PERIPHERALS PUSH FORWARD

FROM MICE AND HEADSETS TO VR AND BEYOND

■ 2021 is shaping up to be another good year for PC peripherals, both in the professional and gaming sectors. A year of working from home has meant that more and more people need good home setups, from quality keyboards to comfortable headsets. 2020 has seen some awesome peripherals with brilliant innovations, from the adjustable actuation point of the switches on the SteelSeries Apex Pro to the widespread implementation of virtual 3D audio in gaming headsets.

So, what does 2021 hold? Let's start with a shiny new headset. Gaming audio expert HyperX has a new one in the works, the wireless Cloud II gaming headset. It packs a 30-hour battery life, 53mm neodymium drivers, and a 2.4GHz wireless connection for minimal audio latency. It also comes with HyperX's excellent noise-cancelling technology in the boom microphone, which is certified by both Discord and TeamSpeak (and us, for the record). Virtual 7.1 surround sound is an obvious inclusion too, all dressed up in the manufacturer's signature black and red, with plush leatherette and memory foam earcups.

We've got some new keyboards coming in too, such as the new Cherry MX-powered models of the awesome One 2 RGB and Mecha Mini v2 from Ducky, replacing previous Kailh-switch versions. Doubleshot PBT keycaps, awesome new switches, and a variety of unique designs make these a very enticing prospect for mechanical keyboard lovers.

In the VR arena, HP has a new model incoming: The Reverb G2. Initial impressions are good, with ergonomic cameras and tracking pairing up with dual 2,160 x 2,160 LCD panels at up to 90fps, for a VR experience that looks set to blow the competing Oculus Rift S and HTC Vive Pro out of the water. Steam functionality comes as standard here, as both the lenses and speakers of the G2 are designed by Valve itself. The speakers look pretty chunky, but sit 10mm off the ear to ensure comfort. It's also one of the lightest VR headsets around, with models starting at just 1.1lbs.

We'd place money on a new model of the HP "VR Backpack" too, a wearable PC designed to support the original Reverb. The previous backpack was a business-targeted product, equipped with an RTX 2080 and 32GB of high-speed RAM, and cost nearly $4,000, so the notion that HP will be willing to send us a review unit is (perhaps!) us getting overexcited. In any case, there's plenty of tech we're looking forward to playing with this year.

THE LIGHT FANTASTIC

You heard it here first: Mechanical switches are dead, long live optical switches. These nifty key switches use light beams broken by depressed keys to register input.

This has a few different advantages over conventional mechanical switches. Obviously, the speed-of-light actuation is a boon for twitchy pro gamer types, but the difference in input registration is measured in milliseconds so won't be that noticeable to the average user. The most important benefit for the consumer is the improved lifespan and repairability; no physical electrical component means that optical switches last considerably longer than their mechanical counterparts, typically for 100 million keypresses or more.

Improvements for the consumer alone won't make a new type of product viable. But optical key switches are easier to design and implement, resulting in lower manufacturing costs and easier repairs. In the long run, optical keys will save manufacturers money—especially if it leads to fewer warranty claims—so it's not hard to see why the keyboard industry is likely to make the shift.

Of course, we're not actually calling time of death on mechanical keyboards. There's still a way to go in developing optical key switches that are better and cheaper to produce, and mechanical switches currently offer greater variety and moddability. Gateron has its own optical switch line, while peripheral manufacturers such as Razer and Asus ROG have developed their own proprietary switches, currently limited to purple clicky and linear red styles respectively.

Ducky's Mecha Mini was seriously kick-ass, and its v2 is expected to be even better.

Optical switches are without a doubt the future of affordable keyboards with a tactile feel.

MAXIMUM PC'S 16TH IRREGULAR

GEEK QUIZ

MAXIM
UNIVE

HAVE YOU BEEN PAYING ATTENTION? TIME TO PROVE IT

BY CHRIS LLOYD

IT'S TIME TO SEE if you've been reading *Maximum PC* diligently and soaking up all the lovely techy knowledge, with one of our famously fiendish quizzes. We've concocted a set of questions that will tax your noodle on everything from processors and other hardware, through Windows, the internet, and onto what's happening in the wider world of technology. Some of the questions are a little sneaky too—few will know the right answer, so you'll have to use your judgment to make an educated guess, unless you really do know everything.

There are seven sections of seven questions. Tot up your scores, and we'll discover what a brain box you are, or if you really shouldn't be left alone with sharp objects. All in good fun.

We do realize that you can just search for the answers online of course. But where would the honor be in that? Try taking this challenge cleanly, and maybe you'll be good enough for the *Maximum PC* College of Geekness. Here we go then, good luck people.

Processor Puzzlers

1 Which of these isn't part of Intel's Foveros die-stacking technology?

A] ☐ MDIO
B] ☐ EMIB
C] ☐ ODO
D] ☐ MEOD

2 Apple claims that its new M1 chip has the world's fastest integrated graphics: How fast?

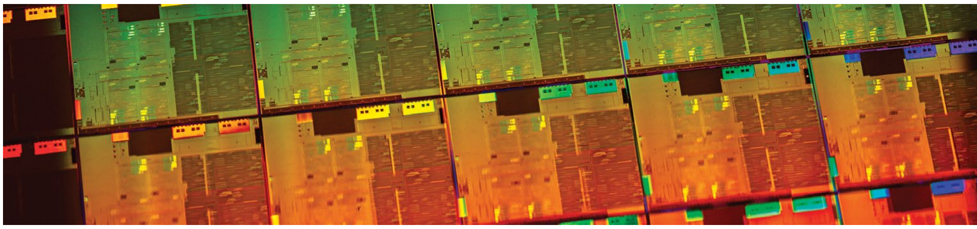
A] ☐ 2.6 teraflops
B] ☐ 2.3 teraflops
C] ☐ 2.1 teraflops
D] ☐ 1.8 teraflops

3 How much L3 cache does AMD's new Zen 3 5000-series chip have?

A] ☐ 32MB
B] ☐ 32MB per CCD
C] ☐ 32MB per CCX
D] ☐ 64MB

4 Which of these Intel microarchitectures is a development of Sunny Cove?

A] ☐ Golden Cove
B] ☐ Goldmont
C] ☐ Amber Lake
D] ☐ Rock Creek



5 **Which is the world's most valuable chip company?**

A] ☐ Nvidia
B] ☐ Intel
C] ☐ TSMC
D] ☐ Samsung

6 **Which of these isn't a real current Intel chip?**

A] ☐ Pentium Gold G5600
B] ☐ Xeon Silver 5218R
C] ☐ Celeron G4930
D] ☐ Core i7-7700T

7 **What kind of chip is the KX-U6780A?**

A] ☐ A processor from a Californian start-up reviving old Texas Instruments designs
B] ☐ A unlicensed Chinese clone of AMD's Epyc
C] ☐ A new Korean SoC for low-cost devices
D] ☐ One of China's first modern x86 processors

© INTEL, PALIT, TSMC

Pixel Pushing

8 **How many hardware ray accelerators does the new Radeon RX 6900 XT have?**

A] ☐ 64
B] ☐ 72
C] ☐ 80
D] ☐ 96

9 **Which isn't a feature of DirectX 12 Ultimate?**

A] ☐ Contrast Adaptive Sharpening
B] ☐ Mesh Shading
C] ☐ Variable Rate Shading
D] ☐ Sampler Feedback

10 **Which of these data formats isn't supported by Nvidia's Ampere hardware JPEG decode**

A] ☐ YUV444
B] ☐ YUV442
C] ☐ YUV400
D] ☐ RGBA

11 **What is Intel's codename for its imminent first discrete graphics card?**

A] ☐ Iris DG1
B] ☐ Iris Xe Max
C] ☐ DG1
D] ☐ DG1 Max

12 **How far does Palit's GeForce RTX 3070 GameRock OC push the boost clock?**

A] ☐ 1,845MHz
B] ☐ 1,810MHz
C] ☐ 1,795MHz
D] ☐ 1,770MHz

13 **What is the maximum screen size on dual screens supported by VESA DisplayPort?**

A] ☐ 16K each
B] ☐ 8K each
C] ☐ 10K each
D] ☐ 16K split as required

14 **What size is the WQXGA video standard?**

A] ☐ 2048 x 1080
B] ☐ 2048 x 1536
C] ☐ 2560 x 1440
D] ☐ 2560 x 1600

Dealing With Bits

15 We finally have a DDR5 memory standard, what's the fastest speed specified so far?

A] ☐ PC5-43200
B] ☐ PC5-51200
C] ☐ PC5-38400
D] ☐ PC5-67200

16 Seagate is about to launch the world's biggest HDD, just how big is it?

A] ☐ 16TB
B] ☐ 18TB
C] ☐ 20TB
D] ☐ 22TB

17 What technological breakthrough enabled such a high capacity?

A] ☐ Using carbon nano-particles embedded in the recording surface
B] ☐ Using a laser during recording
C] ☐ 3DMR, Three Dimensional Magnetic Recording
D] ☐ Electrostatic recording

18 Which one of these technologies isn't used when making memory chips?

A] ☐ Nanosheet FET
B] ☐ FinFET
C] ☐ GAA FET
D] ☐ Min FET

19 What's the minimum number of drives for RAID Level 5?

A] ☐ Two
B] ☐ Three
C] ☐ Four
D] ☐ Six

20 The U.2 interface standard is mechanically identical to which other standard?

A] ☐ M.2
B] ☐ eSATA
C] ☐ SATA Express
D] ☐ SAS

21 The first USB flash drives appeared in the US in 2000, how big were they?

A] ☐ 8MB
B] ☐ 12MB
C] ☐ 16MB
D] ☐ 4MB

Other Hardware

22 USB4 has finally been specified, how fast will it be?

A] ☐ 40GBps
B] ☐ 40Gbps
C] ☐ 32GBps
D] ☐ 32Gbps

23 According to Microsoft's Project Athena, how many hours of "real world" performance should you get from a compliant machine?

A] ☐ 16 hours
B] ☐ 14 hours
C] ☐ 12 hours
D] ☐ 9 hours

24 What is the latest standard for power supplies?

A] ☐ ATX 2.23
B] ☐ ATX 2.13
C] ☐ ATX 2.31
D] ☐ ATX 2.32

25 For what piece of kit is a CFM value used as a metric?

A] ☐ Game controllers
B] ☐ Power supplies
C] ☐ Cooling fans
D] ☐ RGB lighting systems

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26 **What's the resolution of the Valve Index VR headset, per eye?**

A] ☐ 1700 x 1440
B] ☐ 1440 x 1600
C] ☐ 1832 x 1920
D] ☐ 1280 x 1440

27 **MOSFETs are at the heart of which vital sub-system of a PC?**

A] ☐ Voltage regulator modules for CPUs and GPUs
B] ☐ PCIe controllers for cross-talk control
C] ☐ Power supply ripple suppressors
D] ☐ SATA SSDs

28 **Fugaku is now the world's most powerful computer, how many ARM processors does it have?**

A] ☐ 48,096
B] ☐ 88,000
C] ☐ 158,976
D] ☐ 236,448

Software Stuff

29 **Win10 now has over one billion users, but what is that as a percentage of PCs?**

A] ☐ 70.1%
B] ☐ 72.2%
C] ☐ 74.9%
D] ☐ 79.8%

30 **That's good, but how is the Edge browser doing?**

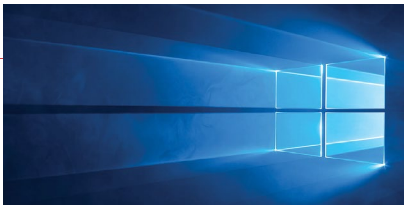
A] ☐ 8.6%
B] ☐ 9.1%
C] ☐ 10.2%
D] ☐ 12.5%

31 **How much RAM can 64-bit Win10 Home use?**

A] ☐ 4GB
B] ☐ 64GB
C] ☐ 128GB
D] ☐ 2TB

32 **Roughly how many distributions of Linux are there?**

A] ☐ 300
B] ☐ 400
C] ☐ 500
D] ☐ 600



33 **How many editions of Win10 are there currently?**

A] ☐ 14
B] ☐ 12
C] ☐ 10
D] ☐ 8

34 **Win10 was destined to be which actual version number of Windows before Microsoft changed it?**

A] ☐ 9.2
B] ☐ 8.1
C] ☐ 7.5
D] ☐ 6.4

35 **What happens when you press the Windows Key+Control+D?**

A] ☐ Creates and switches to a new virtual desktop
B] ☐ Deletes a virtual desktop, if active
C] ☐ Closes the active window, and all other instances of the same application
D] ☐ Starts Cortana listening

HX1200
CORSAIR

Internet Inquiries

36 The world's first website is still running, when was it created?

A] ☐ 1989
B] ☐ 1991
C] ☐ 1993
D] ☐ 1995

37 What proportion of Bitcoins have been irrevocably lost?

A] ☐ Under 12%
B] ☐ Approximately 14%
C] ☐ Approximately 22%
D] ☐ Over 30%

38 Facebook earned a record-braking fine from the FTC last year, how much was it?

A] ☐ $2 billion
B] ☐ $5 billion
C] ☐ $8 billion
D] ☐ $10 billion

39 Which of these Google services hasn't died in the last year?

A] ☐ Google Station
B] ☐ Google Photos Print
C] ☐ Google Fonts
D] ☐ Google Play Music

BITCOIN · DIGITAL · DECENTRALIZED · PEER TO PEER
TROY OZ 999 FINE COPPER
MONETARY METALS

40 What percentage of Americans actually use the internet?

A] ☐ 83.4%
B] ☐ 89.9%
C] ☐ 95.0%
D] ☐ 97.6%

41 Barack Obama has the most Twitter followers, but who is second?

A] ☐ Justin Bieber
B] ☐ Katy Perry
C] ☐ Taylor Swift
D] ☐ Rihanna

42 What does the average "celebrity" YouTube influencer charge a brand for promotion?

A] ☐ $1,605
B] ☐ $2,542
C] ☐ $3,075
D] ☐ $3,857

World of Technology

43 How old is the world's oldest working digital computer?

A] ☐ 1963
B] ☐ 1961
C] ☐ 1959
D] ☐ 1951

44 What happened to the Segway PT this year?

A] ☐ The record for the largest Segway parade was set at 652
B] ☐ It became officially classified as a motorbike in some countries
C] ☐ America won the Segway Polo World Cup
D] ☐ Production was stopped due to poor sales

45 Microsoft had a change of heart this year, about what?

A] ☐ Older engineers, it is to actively hire more experienced people
B] ☐ Windows CE, it is to be used in IoT devices
C] ☐ Open source, it isn't the devil's work
D] ☐ Unauthorized Chinese copies, it is preparing to take action

46 **Tesla recently had a problem with rain, what was it?**

A] ☐ The rear fenders can become detached

B] ☐ The autopilot sometimes refuses to go over 15mph

C] ☐ Water can enter through a panel gap and short the touchscreen

D] ☐ The door locks can fail, leaving owners locked inside

47 **What's unusual about the social media influencer Lil Miquela?**

A] ☐ She was part of a story for *Black Mirror*

B] ☐ She is a CGI creation

C] ☐ She was revealed to be a set of identical triplets

D] ☐ She claims to be a ghost

48 **Which of these isn't one of Elon Musk's observations?**

A] ☐ Humans most likely exist in a video game

B] ☐ If I could I would not eat

C] ☐ I am not 100% sure that NASA actually got to the moon

D] ☐ Aliens built the pyramids

49 **Which of these '"smart" devices isn't available yet, but is still looking for funding?**

A] ☐ A car tire

B] ☐ A beer bottle opener

C] ☐ A deodorant applicator

D] ☐ A teapot

GEEK POINT AVERAGE

Did you resist the temptation to search online? Well done if you did, now add up how many you got right to see how much of a champion you are—or not.

0–12 CORRECT: SUNNYDALE HIGH DROPOUT

By some strange magic you've managed to score below the statistical average for random guesses. We don't know how you managed this, but a blindfolded monkey would do better.

13–15 CORRECT: MOS EISLEY COMMUNITY COLLEGE

Oh dear, this score puts you in the sweet spot for random guesses. Did you make random guesses? If not you are clearly attempting the wrong sort of quiz.

16–28 CORRECT: UNSEEN UNIVERSITY UNDERGRADUATE

OK that's not too bad, you know a thing or two, but you're no expert yet. Keep reading, you'll get there.

29–36 CORRECT: CAL STATE HOGWARTS

If you managed this without cheating then we are moderately impressed, and you've clearly been paying attention. Well done, have an imaginary prize.

37–48 CORRECT: VULCAN INSTITUTE OF TECHNOLOGY

Amazing, you are a real expert and probably spend more time than is healthy thinking digitally. Have a large, shiny, imaginary prize, you've earned it.

49 CORRECT: YOU CHEATED DIDN'T YOU?

ANSWERS

Processor puzzlers 1]**D**, 2]**A**, 3]**B**, 4]**A**, 5]**C**, 6]**B**, 7]**D**. *Pixel pushing* 8]**C**, 9]**A**, 10]**B**, 11]**C**, 12]**A**, 13]**B**, 14]**D**.

Dealing with bits 15]**B**, 16]**C**, 17]**B**, 18]**D**, 19]**B**, 20]**C**, 21]**A**. *Other hardware* 22]**B**, 23]**D**, 24]**C**, 25]**C**, 26]**B**, 27]**A**, 28]**C**.

Software stuff 29]**B**, 30]**C**, 31]**C**, 32]**D**, 33]**B**, 34]**D**, 35]**A**. *Internet inquiries* 36]**B**, 37]**C**, 28]**B**, 39]**C**, 40]**C**, 41]**A**, 42]**C**.

World of technology 43]**D**, 44]**D**, 45]**C**, 46]**A**, 47]**B**, 48]**C**, 49]**B**.

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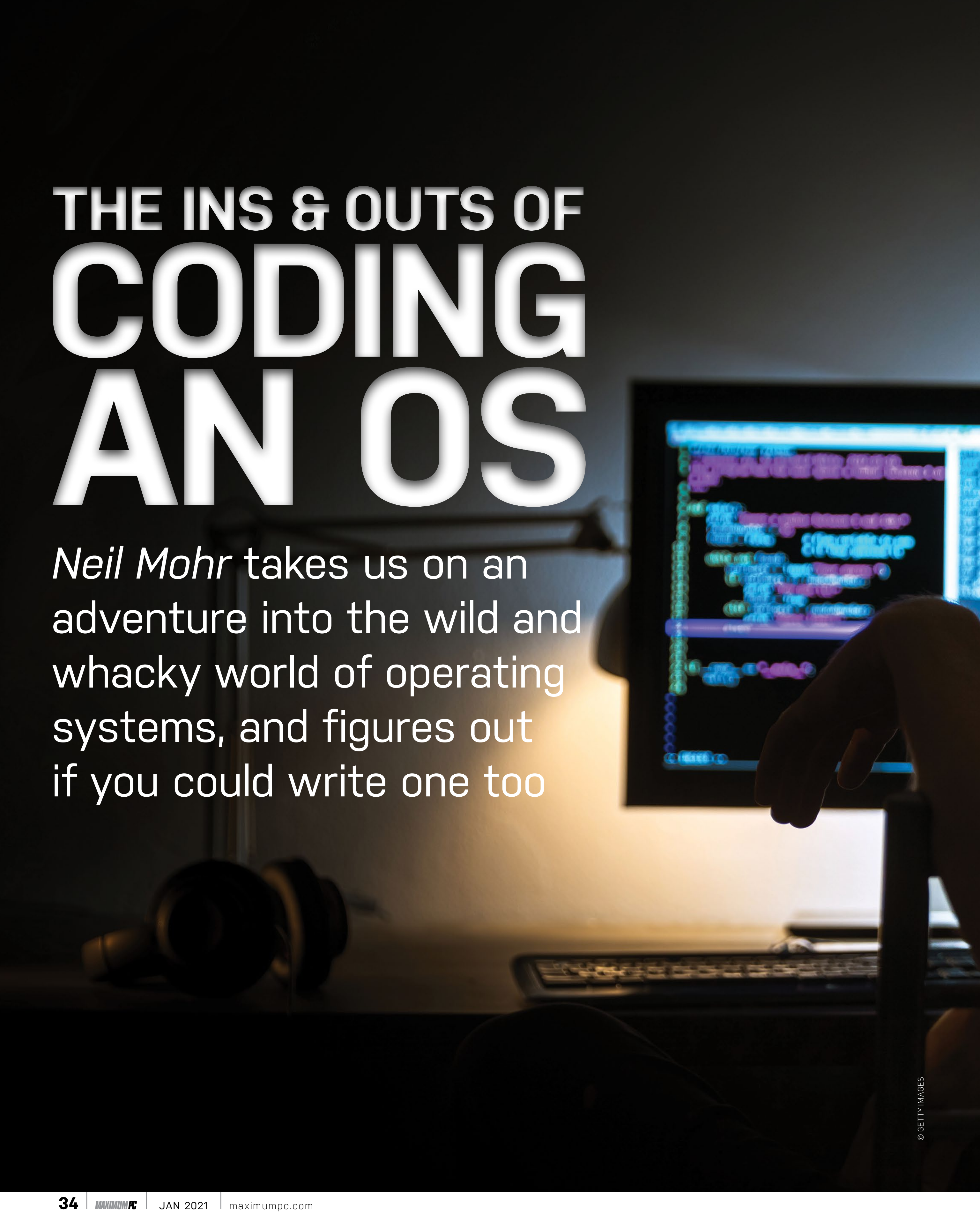
THE INS & OUTS OF CODING AN OS

Neil Mohr takes us on an adventure into the wild and whacky world of operating systems, and figures out if you could write one too



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HAVE YOU EVER WONDERED what makes a PC start and run, I mean really run? Not just hand-waving "the processor boots the operating system" dismissive nonsense, which isn't any more enlightening than saying that stuff is made of atoms. The nuts and bolts when you press the power button and the PSU fires up its 12, 5, and 3-volt lines to the motherboard—how does the processor even know what to start running, and how is that even loaded into memory when there's nothing to run to do that?

We are talking (semi) software level here. If you want to know how individual hardware components work then that's another world of glorious pain to explore—gawping at the level of insanity of the Intel 8088 architecture that leaves you asking "Why would you do that?" is quite the thing. We have to draw the line somewhere, as otherwise we would be descending into what those atoms are up to inside of all that silicon.

This feature is largely spun out of a thought experiment: If you were locked in a room with just a floppy disk and a PC with a blank hard drive, could you get it to boot and run an operating system? Or more to the point, what would you need to do to run an operating system? We're going to answer that in two parts. To kick things off we'll have a look into that thought experiment: What you need to code to get a booting system. Then we'll actually put together an operating system using the Arch Linux build system, so you can see how all those low-level parts plug together to run a modern operating system. Deep breath, we're going in...

I'M A WINDOWS USER GET ME OUT OF HERE!

IT'S HARD TO KNOW just how much we're handled with kid gloves these days as computer users—and this journalist says that from a Linux user's perspective. It's likely that many *Maximum PC* readers will remember children's electronic kits from the 1970s, like Radio Shack's Science Fair Microcomputer Trainer. You had to handwire components to create a suitable circuit, then program the CPU by inputting single commands and variables in hexadecimal. Horrifying, but fun!

It's the sort of barebones introduction to computing electronics that will suitably traumatize a young child into wanting to learn to program. It's also about as far away from how current children are introduced to the subject via sanitized iPads and touchscreen devices. Where's all the fun if there's no screaming "What do you mean I have to wire up the resistors with my bare hands just to make it go beep?"

It's this detachment from the underlying (metaphorical) cogs, wheels, and pulleys of computing that triggered the creation of the Raspberry Pi—and let's never forget that Eben Upton only ever expected to sell a few thousand, not 35 million, which tends to indicate that there's some sort of pent-up demand for this low-level access.

We're going to first look at the various parts a PC needs to power up, before it even boots an operating system. Then, once we've covered the building blocks, we're going to move on to installing Arch Linux. This is one of the distros that requires a more "hands on" approach to getting it up and running, but some variants like Gentoo (that requires compiling every element from source) or Linux From Scratch (which is actually a book) take things even further.

To kick things off, the first thing to do is cheat. We're going to presume that our dead PC has a working BIOS. We could try and argue that since this is firmware it's actually more like hardware, as it's baked into the EEPROM, but it's still software. As we'll cover later, without the BIOS you'd have a hard time doing anything: You'd have to first program the EEPROM using a dedicated system, and it's highly tailored to the hardware.

The BIOS is the lowest level that software can interface with the hardware. At initial power on, accessing storage, display, audio, and other peripherals is only possible through the BIOS via interrupt calls. So without it we're a bit stuck.

When you first press the power button, the PSU powers up the ATX cables, so SATA drives are directly powered, the motherboard, and GPU. The PSU can take a second or so to build a reliable power supply, and the chipset generates a reset signal for the processor (as if you're pressing reset) until it gets a Power Good signal from the PSU. Devices such as memory have fixed logic and will initialize; more complex devices such as a GPU or network cards will have their own firmware that will initialize.

Of course an open-source project has a terrible logo!

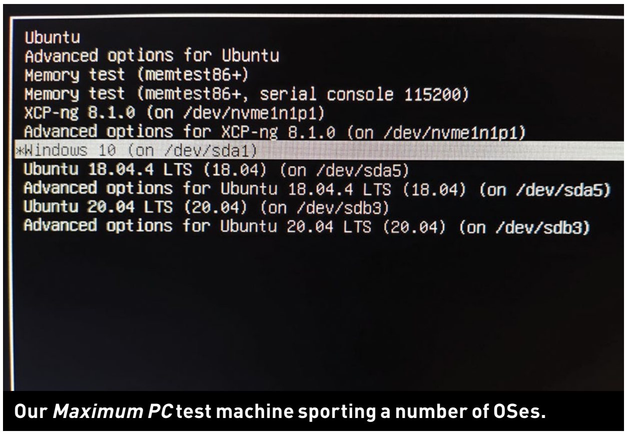
The reset signal is released, and the CPU powers up with a randomly selected single core, but requires something to run since the memory is blank. The original behavior is to have the first instruction mapped from EEPROM memory to 0xFFFF0h (1MB)—the maximum memory for 16-bit minus 16 bytes—the modern behavior is 0xFFFFFFF0h (4GB)—the same but for 32-bit address space. That first command, called the reset vector, is always a long jump to where the BIOS is actually located —usually 0xF00000.

At this point your PC can run its Power On Self Test software. This largely initializes CPU registers, verifies the BIOS, verifies DMA, the timer and the interrupt controller, verifies system memory, and verifies boot devices. On modern systems this extends to verifying all system buses (USB, PCIe etc), devices and, displays. It also initializes the Advanced Configuration Power Interface (ACPI), setting the data in memory for use by the operating system kernel.

If a serious error is encountered that stops the system boot proceeding, the BIOS can communicate that in a number of ways: A screen error message or code; a series of audible beeps; or it can transmit an error over the PCI bus to a suitable debug card.

But if, as is often the case, everything goes well, then the BIOS is ready to hand off control of the PC to an operating system, but how? All that verifying buses and devices comes in rather handy at this point, as it'll have a list of supported storage devices attached to detected buses. In the olden days this would just be the floppy drive, or the primary IDE hard drive. Today it could have a huge list of possibilities, as many of you might know from your own UEFI boot options.

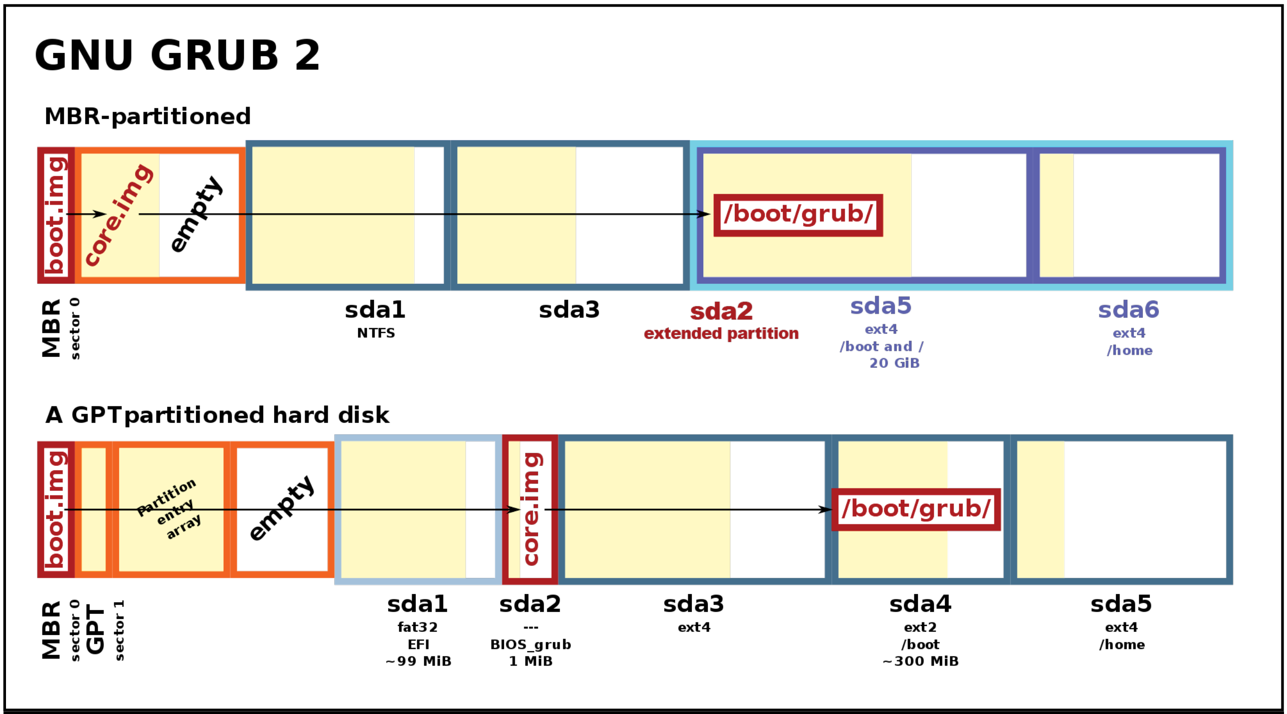
It doesn't matter if it's an NMVe or a USB stick, the hand-off sequence is the same: The BIOS loads the first 512 bytes from the selected boot device—what we call the Master Boot Record (MBR)—it's literally the first sector of a drive and is loaded into memory and directs the processor to run this code. The 512 bytes is even more limited than you'd think, as it also has to contain the



```
Ubuntu
Advanced options for Ubuntu
Memory test (memtest86+)
Memory test (memtest86+, serial console 115200)
XCP-ng 8.1.0 (on /dev/nvme1n1p1)
Advanced options for XCP-ng 8.1.0 (on /dev/nvme1n1p1)
*Windows 10 (on /dev/sda1)
Ubuntu 18.04.4 LTS (18.04) (on /dev/sda5)
Advanced options for Ubuntu 18.04.4 LTS (18.04) (on /dev/sda5)
Ubuntu 20.04 LTS (20.04) (on /dev/sdb3)
Advanced options for Ubuntu 20.04 LTS (20.04) (on /dev/sdb3)
```

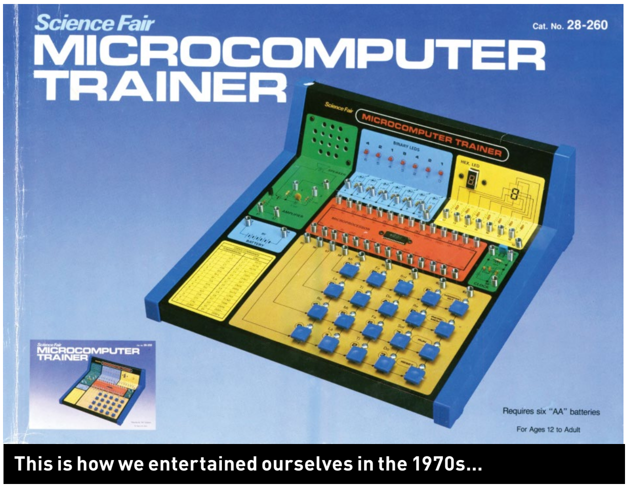
Our *Maximum PC* test machine sporting a number of OSes.

© GRUB


GNU GRUB 2
MBR-partitioned
boot.img
core.img
empty
/boot/grub/
MBR
sector 0
sda1
NTFS
sda3
sda2
extended partition
sda5
ext4
/boot and /
20 GiB
sda6
ext4
/home
A GPTpartitioned hard disk
boot.img
Partition entry array
empty
core.img
/boot/grub/
MBR
sector 0
GPT
sector 1
sda1
fat32
EFI
~99 MiB
sda2

BIOS_grub
1 MiB
sda3
ext4
sda4
ext2
/boot
~300 MiB
sda5
ext4
/home

Here's a visual of how Grub transverses its multi-stage bootloader from MBR, root partition, config file to OS kernel.


Science Fair
MICROCOMPUTER TRAINER
Cat. No. 28-260
Requires six "AA" batteries
For Ages 12 to Adult

This is how we entertained ourselves in the 1970s...

basic partition table, limited to just four—one that can be marked as the "Active" boot partition, plus an end Boot Signature of 0x55, 0xAA that shows the drive is bootable.

As you can imagine, this isn't any space to do much more than redirect the processor to where there's more code to run. So the MBR is often called the Stage One Bootloader. On standard Windows systems the code directs the BIOS to load the first sector—so another 512 bytes—of the active-marked partition in the partition table into memory, and run that.

As an aside, be aware that UEFI firmware has supplanted the MBR on modern PCs, as the UEFI can directly understand drive and partition layouts and can store boot code on a FAT32 partition, doing away with the MBR's limitation—a major limit to the MBR being a 2TB multi and 4TB single-partition limit, though MBR remains backwards-compatible with (U)EFI systems.

ARE WE THERE YET?

We're getting there, the fuse is burning but the main event hasn't quite ignited. At this point the MBR code loads the first three bytes of the active-partition's first sector. This is a JMP command telling the system how far ahead to go to load the Second Stage Bootloader, and we can almost start our operating system kernel.

The main aim of the Second Stage bootloader is to load its configuration file, present any required user menu, and then to hand off to the operating system kernel with any required options—often recovery modes or older kernels. As this bootloader is required to access a file as part of a high-level file system (FAT32, NTFS, ext2/4) there's a lot more complexity.

You would imagine it'd be easy to use hard-coded settings in many areas of this boot chain, but while it could work, it wouldn't be very flexible, and a single change would cause the entire thing to fail. All the major bootloaders store a configuration file that's loaded at boot-time from which any boot options are created.

Windows NT, 2000, and XP used the NTLDR bootloader that stores a boot.ini file on the root of the active partition. It also used the NTDETECT.COM tool to detect devices. Windows Vista and onwards use BOOTMGR, which maintains a BOOT folder with a BCD (Boot Configuration Database) binary configuration file. BOOTMGR was designed to support modern GPT and UEFI configurations, and its BCD cannot be edited by hand.

Most open-source OSes use Grub 2 (GRand Unified Bootloader). Released in 2012, this stores a grub.cfg in a /boot/grug/ folder either on its own boot partition or in the base folder of the boot operating system.

Many Windows users won't notice anything, and Windows will start up. However, your Second Stage Bootload can support multiple operating systems on a single system in a multi-boot format. Selecting the OS you want to boot kicks off the final stage of the bootloader process.

Depending on the OS and type of kernel, the bootloader will load the kernel image from the path specified in the configuration file into the memory. It points the CPU to JMP to a certain location within the kernel and starts running the operating system.

© SHMUEL CSABA OTTO TRAIAN/WIKIPEDIA, GRUB, POLYLITH

LET'S BUILD AN OS!

IN AN OLD REDDIT THREAD someone once asked, "If you were locked in a room with a PC with no OS, could you write one from scratch?" Among all the joke replies, someone actually answered that question—Kragen Javier Sitaker, who worked for Canonical (the company that publishes Ubuntu) at the time.

Sitaker's approach took a number of steps to implement the base functionality that's needed to get an OS up and running, though this hinges on there being a functioning IBM PC-compatible BIOS. He then piggybacked off the bootloader to implement his base features.

On the previous spread we alluded to the BIOS providing base access to devices. This is done via interrupts, and enables the minimal bootloaders to get an OS kernel up and running, and indeed enable the kernel to bootstrap itself into life. Interrupt calls cover everything from writing to the screen (10h), read/write to storage devices (13h), serial port access (14h), read the keyboard (16h), and access the PCI bus (1Ah).

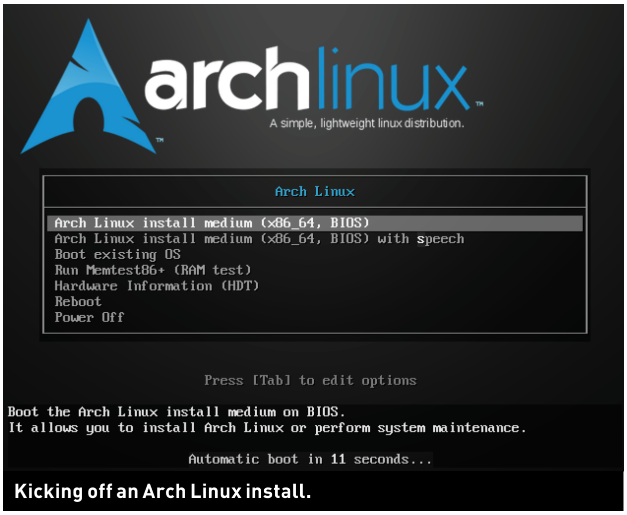
Using the Intel 8088 ah and al registers, you could print a "!" character to the screen using `screen function 0Eh` and interrupt call 10h in assembler like so:

```
mov ah, 0x0e       ; function number = 0Eh : Display Character
mov al, '!'        ; al = character to display
int 0x10           ; call INT 10h, BIOS video service
```

You hopefully get the picture, or else trust us that you can get the BIOS to do basic stuff, otherwise how else do you think BIOS menus were created and managed?

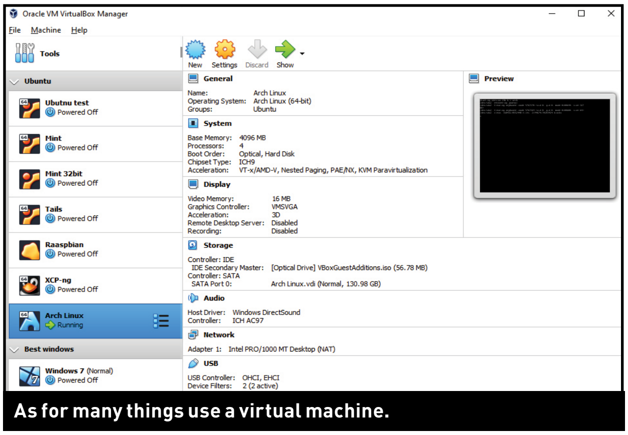
To get anywhere with this, the first thing you need is a way to enter machine code into the computer and jump the processor to it. This is called a machine code "monitor." They used to be all the rage, but for some reason have fallen out of favor with the kids, but Sitaker wrote a super-basic one in C like this:

```
    int main(int argc, char **argv) {
      for (;;) {
        char c = getchar();
        if (c == '.') return 0;
        char d = getchar();
        putchar(((c & 0xf) << 4) | (d & 0xf));
      }
    }
```



```
                    Arch Linux

 Arch Linux install medium (x86_64, BIOS)
 Arch Linux install medium (x86_64, BIOS) with speech
 Boot existing OS
 Run Memtest86+ (RAM test)
 Hardware Information (HDT)
 Reboot
 Power Off


              Press [Tab] to edit options

Boot the Arch Linux install medium on BIOS.
It allows you to install Arch Linux or perform system maintenance.

              Automatic boot in 11 seconds...
```

Kicking off an Arch Linux install.



General
Name: Arch Linux
Operating System: Arch Linux (64-bit)
Groups: Ubuntu

System
Base Memory: 4096 MB
Processors: 4
Boot Order: Optical, Hard Disk
Chipset Type: ICH9
Acceleration: VT-x/AMD-V, Nested Paging, PAE/NX, KVM Paravirtualization

Display
Video Memory: 16 MB
Graphics Controller: VMSVGA
Acceleration: 3D
Remote Desktop Server: Disabled
Recording: Disabled

Storage
Controller: IDE
IDE Secondary Master: [Optical Drive] VBoxGuestAdditions.iso (56.78 MB)
Controller: SATA
SATA Port 0: Arch Linux.vdi (Normal, 130.98 GB)

Audio
Host Driver: Windows DirectSound
Controller: ICH AC97

Network
Adapter 1: Intel PRO/1000 MT Desktop (NAT)

USB
USB Controller: OHCI, EHCI
Device Filters: 2 (2 active)

As for many things use a virtual machine.

The getchar() and putchar() are BIOS interrupt calls. If you want to look it up, AH = 01h, Int 21 reads a character with echo, while for getchar() and AH = 02h, Int 21 writes a character to standard output.

In the magic scenario you have to hand, translate this into assembly, and then machine code and somehow get it onto the bootsector of your floppy. Let's do some hand-waving and pretend that's part of the rules.

With this, the PC would now boot the super-basic machine code monitor into memory and run it. At this point you'd want to write the monitor to the main area of the floppy, but enhance it with "modern" features like backspace, displaying what you're entering, and other basic editor features. Displaying areas of memory, changing the target address, and interrupting looped code would all be on your To Do list. Adjust the first-stage bootloader to JMP to this new monitor on the floppy, and you're cooking with machine code.

Typing pure machine code octal by octal is no fun, even in your swanky feature-ladened monitor. So the next step is to create a basic assembler. We'll start to plough through these, but the assembler lets you code with case-sensitive letters for instructions. Write this in your monitor and save it to a blank area on your floppy.

But even assembly is a pain, so to speed development of your proto OS you'll first want to develop a high-level language, Sitaker used Forth, but it really doesn't matter. If you're wondering, Sitaker has a 66-line, self-compiling Forth working example here https://github.com/kragen/stoneknifeforth.

With that safely on your floppy, you'll want to create a minimal file system so you can create, load, and develop new commands in your Forth editor without the worry of overwriting things. You'll then want a basic set of commands for managing those files—delete, move, rename, list files, and copy. A basic compression tool would help speed things along, and why not redevelop your assembler and implement a text editor rather than editing memory directly?

Currently, and we've not mentioned it, everything here is running in Intel's 16-bit real mode, which is sort of the 8088 fallback mode. That's right, it's not very good. If you wanted to go on and develop this further you'd want to re-compile everything now to work in 32-bit protected mode, which enables full memory space access, along with strict memory and I/O protection.

You can go to set the screen via the BIOS to 640x480 in 16 bits, develop libraries to draw primitives, manage these as windows, create a desktop system to keep them all on, monitor a mouse pointer, and Bob's your proto-OS.

© LINUX FROM SCRATCH, ARCH LINUX

If you're feeling brave, try linuxfromscratch.org

ENTER THE ARCH

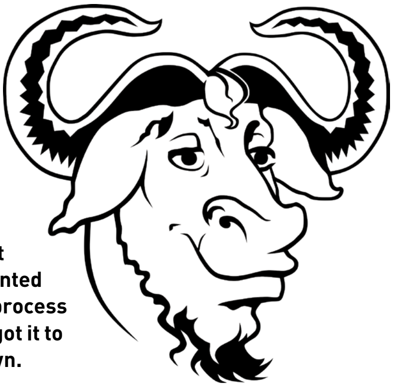
To put all this "fun" behind us but continue on our quest for a working operating system, we're going to continue with Arch Linux. Arch has a reputation among Linux distros for being in-depth and has coined the meme "I use Arch btw," as some users tend to throw it around as a mark of superiority. It's a very nuts and bolts distro, expecting you to do much of the configuration, and you'll need to install a GUI desktop, if you want one. But it has the best documentation on the planet, and its software repositories are the most up to date, with it generally being the first distro to make new kernels and software available via its rolling update system.

So if truth be told, this guide isn't going to be much more than a targeted rewrite of the core install guide (which you should check out at https://wiki.archlinux.org/index.php/installation_guide). We'll focus on installing on a VirtualBox machine and so specify settings and cut some corners to fit that.

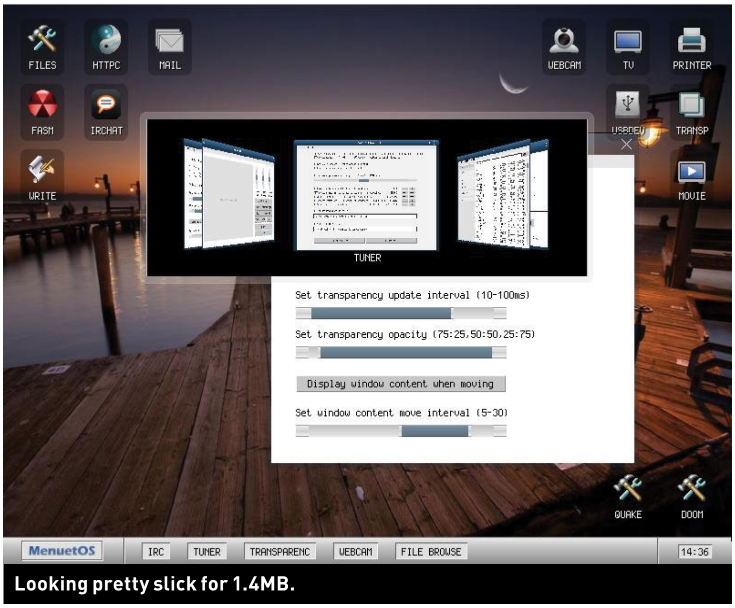
BLESS GNU

If all of this sounds super-crazy, back in 1983 Richard Stallman created the GNU Project (GNU is Not Unix), and the first items to be developed were the GNU C compiler GCC (it remains one of the leading compilers today), the EMACS text editor, the GNU Coreutils (file manipulation), the GNU Bash shell, and the GNU C library glibc, which provides the basic function calls to enable C to work on a system. All of these tools developed 35 years ago are still used within most open-source operating systems to one degree or another today.

So while this might seem just a bit of silly fun, it does genuinely outline the basic building blocks and steps required to boot a computer. And absolutely with older BIOS systems this is the process, and as you can imagine, there was very much a need for the UEFI system to replace all this antiquated bootstrapping. It also turns out that if you're a seriously gifted coder it can work—like Kragen Javier Sitaker, who just for fun implemented and tested this process in DOSBOX and got it to work. Mind blown.



THE WEIRD ALT OS WORLD



Set transparency update interval (10-100ms)

Set transparency opacity (75:25,50:50,25:75)

Display window content when moving

Set window content move interval (5-30)

Looking pretty slick for 1.4MB.

Haha, fit a graphical OS on a floppy disk, crazy talk, right? It is until you go and look at http://menuetos.net which is a graphical OS that fits on a floppy disk. Like many of these alternative tiny operating systems, it's entirely written in assembly and yet supports 64-bit CPUs, 32GB of RAM, USB 2.0 devices, a full TCP/IP stack, full GUI toolkit and 1080p in 24-bit color. But can it play *Crysis*? No, no it can't.

There is a small but active world of alternative operating systems. Some like AROS.org are education-based projects spun out of an older operating system, an API-compatible implementation of AmigaOS but entirely open source and for modern hardware. Others like MikeOS (http://mikeos.sourceforge.net) are created by highly intelligent people that fancy the challenge of creating an entire OS from scratch. While perhaps standing on its own is TempleOS.org (rest in peace Terry A Davis) created as a literal mission from God written in assembly and its own HolyC language.

© ORACLE, GNU, MENUETOS

INSTALLING ARCH LINUX

BEFORE YOU CAN DO ANYTHING you'll want to start the ISO downloading for the Arch Linux install image. Head to www.archlinux.org/download and grab one of the torrents, or else scroll down to one of the localized mirrors.

Best practice is to run an integrity check on the download file—this ensures that it's downloaded correctly but also that no one has interfered with the stored file. Technically the ISO file and checksum hash should be stored on different systems, so it's harder to compromise both.

The easiest way is to use a hasher, such as IgorWare Hasher (www.igorware.com/hasher) for Windows types, load the ISO file and click "Calculate." The generated SHA-1 and MD5 hash should match that on the Arch Linux download page. You can copy and paste it to save you reading a long hexadecimal number.

If you're thinking of installing this onto a real PC then you'll need to burn the ISO to a CD/DVD (remember those things) or more likely use Etcher.io to write it to a USB stick. Reboot your system, and activate its boot menu via the correct function key, usually one of F2, F10, or F12 to boot your PC from the USB device.

We're going to opt for the sensible angle of installing using a VirtualBox.org. Create a new 64-bit machine, ideally with 4GB of memory, but 2GB or even 1GB is fine. Set a hard drive of at least 20GB, ICH9 chipset, VMSVGA graphics, 3D acceleration won't hurt. Point the optical drive at the Arch ISO image and fire it up.

At the Arch Grub—remember that?—boot menu choose the top option to kick off installation. Typically you'd first set your keyboard mapping so you can type in stuff—as it defaults to the US, we're all good. If you need to, list the available keyboards (there are a lot, you probably want the /qwerty/ folder) with:

`ls /usr/share/kbd/keymaps/**/*.map.gz | more`

And activate the one you want with `loadkeys <keymapname>` for example: `loadkeys uk`

We should also check what type of firmware the PC is using, EFI or BIOS/CSM. To see if the EFI folder exists, type: `ls /sys/firmware/efi/efivars`

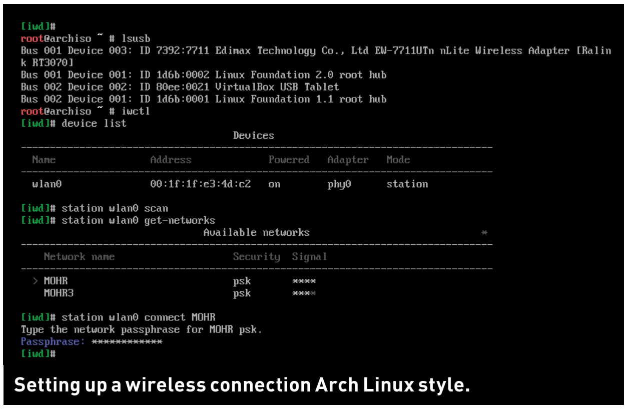
If it does exist you're on an EFI system, if not it's the old BIOS. This changes the partition layout required. If you were expecting something different you'll need to check your UEFI settings—for our VirtualBox it's using the old BIOS by default. If you want, you can create VirtualBox machines running EFI.

To run updates, the system will need an active network connection. For VirtualBox systems and most PCs with a wired Ethernet connection this'll just be up and running, and the DHCP will be active. You can test it via: `ip link` and: `ping archlinux.org`

If you're on actual real hardware with a wireless adaptor you'll need to connect to a network.

You should check to see if the hardware is recognized and working. If it's not you're a little bit stuck, as adding kernel modules is outside this tutorial, though it's not hard: Discover the hardware manufacturer and model, search for and download the kernel module (the driver), and add the module via `modprobe <module name>`.

An easy ways to check for an internal PCI adaptor is to use: `lspci` and look for a wireless network device. For USB dongles use: `lsusb` and do the same. Adding a wireless network is more involved: With the Intel-developed configure tool, type: `iwctl`



```
[iwd]#
root@archiso ~ # lsusb
Bus 001 Device 003: ID 7392:7711 Edimax Technology Co., Ltd EW-7711UTn nLite Wireless Adapter [Ralin
k RT3070]
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 002 Device 002: ID 80ee:0021 VirtualBox USB Tablet
Bus 002 Device 001: ID 1d6b:0001 Linux Foundation 1.1 root hub
root@archiso ~ # iwctl
[iwd]# device list
                                    Devices
--------------------------------------------------------------------------------
  Name                  Address               Powered   Adapter   Mode
--------------------------------------------------------------------------------
  wlan0                 00:1f:1f:e3:4d:c2     on        phy0      station

[iwd]# station wlan0 scan
[iwd]# station wlan0 get-networks
                               Available networks                             *
--------------------------------------------------------------------------------
    Network name                          Security  Signal
--------------------------------------------------------------------------------
  > MOHR                                  psk       ****
    MOHR3                                 psk       ****

[iwd]# station wlan0 connect MOHR
Type the network passphrase for MOHR psk.
Passphrase: ************
[iwd]#
```

Setting up a wireless connection Arch Linux style.

© ARCH LINUX

This provides an interactive prompt, type `help` at any point, use Tab to autocomplete commands and station names. A basic session (ignore #comments) would go like:

`device list` #lists compatible wireless devices

`station <device name> scan` #scan for SSIDs on the selected device

`station <device name> get-networks` #list detected SSIDs

`station <device name> connect <SSID name>` #connect, you'll be prompted for the passkey

`Exit` #takes you back to the prompt

At this point you're good to prepare the main drive, create the partitions, and initialize the filesystems. BIOS and UEFI systems have two slightly different layouts: UEFI ones require a dedicated FAT32 partition for the second stage bootloader as the first partition, whereas BIOS just requires the root storage partition—often there's a second for swap, but that's growing out of fashion.

To list all attached block storage devices, type: `lsblk`

Ignore "loop" and "rom," we just want "disk" types. For our VirtualBox example and SATA-based PCs this device is sda; for NVMe and flash-storage devices this is `nvme0n1` and `mmcblk0` —yes, zero naming consistency, welcome to Linux.

Similarly, using the old DOS partition tool fdisk, type `fdisk -l` for a bit more information. To kick things off, type the full path of the device you want to set up: `fdisk /dev/sda`

First, create your two new partitions in order: The small EFI one and the main Linux root. You can skip this first one for BIOS systems, but it'll work either way. Tap `n` to create a new partition `n`, `p` for primary, Return for default, Return for default, and `+512M` to make it 512MB in size. Tap `t` to change the type and select EFI for us this is type `ef`.

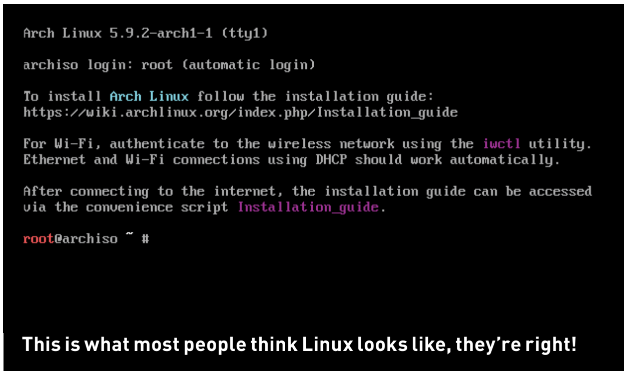
To create the main root partition, type `n`, default, default, default, default to use the whole remaining space. Type `w` to write these changes and exit. It's now necessary to create the filesystems; the EFI one is FAT32 while the main one is the Linux native ext4 format.

```
mkfs.fat -F32 /dev/sda1
mkfs.ext4 /dev/sad2
```

The partitions have been created, formatted, but Linux requires specific partitions to be mounted to make them accessible. For the EFI two partition setup this will be the /dev/sda2 partition.

```
mount /dev/sda2 /mnt
```

Before you trigger the main install process, you need to ensure that the mirrors are the best available for our locality. You're going to run a number of commands to prep the install for updates.



```
Arch Linux 5.9.2-arch1-1 (tty1)

archiso login: root (automatic login)

To install Arch Linux follow the installation guide:
https://wiki.archlinux.org/index.php/Installation_guide

For Wi-Fi, authenticate to the wireless network using the iwctl utility.
Ethernet and Wi-Fi connections using DHCP should work automatically.

After connecting to the internet, the installation guide can be accessed
via the convenience script Installation_guide.

root@archiso ~ #
```

This is what most people think Linux looks like, they're right!

Pacman is the Arch Package Manager tool—you'll use this a lot if you stick with Arch. First, synchronize the main repository ready for installing software, install a tool called reflector, and use it to ready a list of the 12 latest, fastest US mirrors.

```
pacman -Syy
pacman -S reflector
reflector -c “US” -f 12 -l 10 -n 12 --save /etc/pacman.d/mirrorlist
```

The majority of the packages can be installed via the pacstrap script. Leave this to download all the base files and get a cup of coffee. If it fails or stall you can simple re-run it:

```
pacstrap /mnt base linux linux-firmware nano
```

At this point the base OS is installed, but you have to do some tedious but necessary housekeeping. The first item is to store the partition mount configuration in the FilesystemTable, or fstab, so the OS knows what to mount at boot time. You're currently still running off the ISO image, change root with chroot to your newly installed /mnt and then set the timezone settings. Choose a suitable timezone, or use the UTC.

```
genfstab -U /mnt >> /mnt/etc/fstab
arch-chroot /mnt
timedatectl list-timezones
timedatectl set-timezone UTC
```

Another set of settings that is often taken for granted is the locale. This defines the language, number system, date format, and default currency. This is a little messy, but you need to first edit a large config file of possible locales.

```
nano /etc/locale.gen
```

Locate the line `#en_US.UTF-8 UTF-8` and remove the # and press Ctrl + O (output) to save and Ctrl + X to exit. Then finish it off with:

```
locale-gen
echo LANG=en_US.UTF-8 > /etc/locale.conf
```

Now to set the base local networking settings that are rarely considered. First, create a hostname for your system; the "pc-name" can be anything you like:

```
Echo pcname > /etc/hostname
nano /etc/hosts
```

The last command fires up a text editor with a new hosts file, add to it these lines, and remember to change “pcname.” Press Ctrl + O to save (output) the file and then Ctrl + X to exit:

```
127.0.0.1   localhost
::1         localhost
127.0.1.1   pcname
```

Finally, initiate the network manage, and set a password for the base admin account—the username is root:

```
systemctl enable NetworkManager.service
passwd
```

And finally (really this time), we have to install the Grub bootloader on our non-EFI system. It takes three commands: The first installs Grub itself, the next installs Grub onto the boot partition, and the final one creates the bootloader config file it'll need when kicked into life.

```
pacman -S grub
grub-install /dev/sda
grub-mkconfig -o /boot/grub/grub.cf
```

If you were on an EFI system things would look similar but require extra steps to create the /boot/efi folder and mount the boot partition like this:

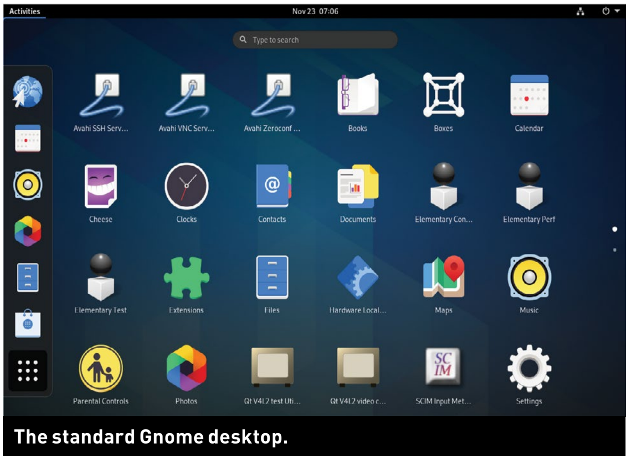
```
pacman -S grub efibootmgr
mkdir /boot/efi
mount /dev/sda1 /boot/efi
grub-install --target=x86_64-efi --bootloader-id=GRUB --efi-directory=/boot/efi
grub-mkconfig -o /boot/grub/grub.cfg
```

At this point you could reboot—remember to remove the ISO image—and log into your Arch install. You'll be left at a command prompt, but you have a Linux install that powers a good portion of the internet. However, as we're here we might as well install the standard GUI called Gnome. We'd love to delve into just how mind-numbingly complex modern graphical interfaces are, but instead we'll just let you gawp at the 2GB install triggered by these two commands:

```
pacman -S xorg
pacman -S gnome
systemctl start gdm.service
systemctl enable gdm.service
exit
shutdown now
```

Remove the USB stick or ISO image file, fire up your Arch install and log in as root using your password and welcome to Arch Linux using the base Gnome interface.

Hopefully you will now feel a little more enlightened about how PCs tick, and especially what's required to get them to boot.



The standard Gnome desktop.

BUILD A SMART HOME OFFICE

Wiseguy *Jonni Bidwell* has some tips on making our homes and home offices smarter, with the latest FOSS offerings

CREATIVE INGENUITY and the ability to cram a network stack into the smallest of things have gifted us, over the past few years, some pretty cool home innovations. Legacy (classical?) home dwellers may see little merit in upgrading to a smart home, but we have some uniquely Linux ideas that may persuade them.

Having a smart home needn't mean having Alexa (the voice of Amazon's Echo) eavesdropping on your every word. Nor does it mean the nameless entity within a Google Assistant reporting back to the mothership whenever you leave the bathroom light on. The Mycroft home assistant can do all the good bits of these voice devices, but without the more chilling data-collection aspects. Best of all, you can run Mycroft on a Raspberry Pi.

But there's more to smart homes than shouting at small robots. As autumn makes its way to the US (and other Northern Hemsiphere places), good citizens will be collectively donning long johns and firing up their boilers, heatpumps and sacrificial pyres. Some may find themselves having to shoulder the expense of a new boiler; others will want to see if their current one can be hacked and tweaked to make for a more economical winter. Through the magic of OpenHAB, we'll show you how.

For many of us, the pandemic has seen our homes become unwitting extensions of the workplace, and depending on your line of work that may be the case for some months to come. So we've got a couple of projects for smartening your home office setup, too. Rescue yourself from Zoom meetings and banish Google's office suite with the open-source powerhouses Jitsi Meet and Collabora Online. And since Docker is all the rage, we'll look at how we can harness its power better using the Portainer management engine. This will make it easy for you to add any service you can imagine to your self-hosted smart home office, so let's get started!

A SMART HOME OFFICE?

Take a look at some great tools that can make a smart home smart, and a home office, er, official

TO THE CYNIC, all this new smartification of everyday items seems to involve putting networked computers in places where they're not needed, and needing dozens of companion apps on your smartphone to keep tabs on all these smart things—and in so doing, opening all these devices (and possibly your phone too) up to attack.

Some manufacturers are better than others at keeping their IoT things secured, and many attacks could be prevented by users changing default credentials. Since 2016, Raspberry Pis no longer ship with the SSH service enabled because it's too easy to spot them when they're exposed to the internet.

WATCH THIS!

But there's a lot of smarthome projects that are fun, safe, and will bring some degree of joy to your home. Lots of these are variations on standard Pi maker projects—we really like, for example, Elio Struyf's project documented at www.eliostruyf.com/diy-building-busy-light-show-microsoft-teams-presence. This uses an LED array as a status indicator for outside your home office.

The pandemic has gotten lots of us quite used to video-conferencing, and with that comes the terrible fear of children (or grown-up children) interrupting your work chatter. Perhaps a brightly colored warning light, which in this case hooks in to your Microsoft Teams account (it could be adapted to other services) to show that your status is "busy" will reduce interruptions?

Home security systems are all the rage too. Again, the Raspberry Pi is excellent at this—you could adapt our motionEye tutorial from page 58 to set this up, rather than going with an off-the-shelf product: Besides security concerns, such products could at any point stop being supported by the manufacturer, which effectively makes them useless. This very thing happened when Google bought Nest back in 2014. Then last year Google announced it was shutting down the Works With Nest program, effectively bricking all the legacy Nest hardware that wasn't produced by Google.

In theory this could happen with open-source projects too, but if it does, then at least the code is all there for someone else to take over the reins.

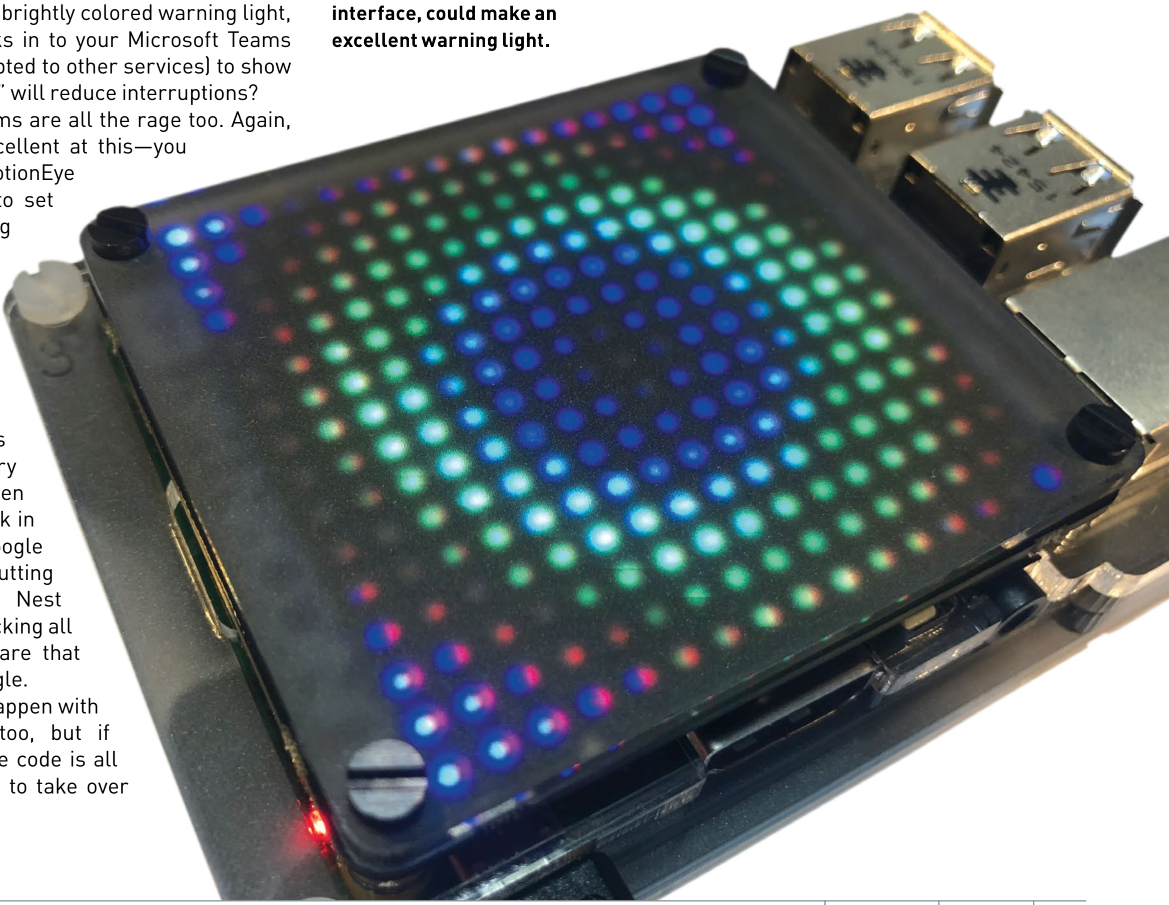
HOT SMART STUFF

Utility companies are keen for everyone to have smart meters now, and these go in tandem with smart boilers, smart thermostats, smart fridges. In theory these can save you money, and it's certainly satisfying being able to pre-warm your house as you travel home.

We'll show you how you can connect all of these together through openHAB, the open-source Home Automation Bus. No smarthome would be complete without a voice assistant, so we'll revisit our old friend Mycroft over the page too.

We're also embracing Docker this issue, so we'll look at using that to smarten up your home office setup, using the Nextcloud cloud-productivity suite. Then we've got some tips on containing this container overload with Portainer, a management engine.

We'll also show you how to set up your very own video-conferencing service with Jitsi Meet. It's going to be an action-packed few pages, so get yourself a cup of coffee and enjoy!



The Unicorn HD, with its 256 RGB LEDs and Python interface, could make an excellent warning light.

OPENHAB AND MYCROFT

Use the power of Ubuntu's openHAB appliance and the Mycroft Voice Assistant to voice-enable your home

THE OPEN HOME AUTOMATION BUS, (openHAB) can connect all the diverse IoT appliances that may or may not be beginning to proliferate around your home. Typically these devices all have their own, often proprietary applications, but under the hood they usually use-open source protocols—and when they don't, people have figured them out enough to plug them into openHAB. We're going to do it a little differently to how we would before, because Canonical recently released the openHAB Ubuntu Appliance for the Raspberry Pi. This means we can write the SD card image, boot it and have a fully functional web-based home automation server.

In order to use these Ubuntu Appliances (there are currently four others besides openHAB, and more are on the way), you'll need to sign up for Ubuntu SSO (Single Sign On) at https://login.ubuntu.com. It's free, and you can use it all over the Ubuntu web ecosystem. Once you've done this you'll want to generate an SSH keypair and upload the public key, so that you can use your SSH-reinforced SSO to log in to your appliance. You may already have generated an SSH key, in which case you probably don't want to overwrite it. Check by running

```
$ ls ~/.ssh/id_rsa.pub
```

If no such file exists, generate it with

```
$ ssh-keygen -t rsa
```

and press "Enter" to accept the default location. Once the key is generated, run `cat ~/.ssh/id_rsa.pub` and copy the contents to the clipboard. Log into Ubuntu SSO and, go to the SSH keys section. Paste the contents into the Public SSH Key box and hit the import button. You can now SSH into Ubuntu services and appliances (from this machine only) using this key. But you still need to log your appliance into Ubuntu's cloud to fetch it, so follow the three steps below and do that.

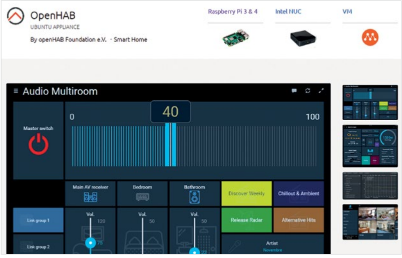
Once setup is complete, take a note of your Pi's IP address and connect to it from a browser by entering, for example, http://192.168.0.2:8080. The openHAB interface can be a little confusing at first, especially given that the first step is "choose an interface." You can always return to this index page to explore the others. Choose PaperUI and peruse what Bindings (in the "Add-ons" section) are available, and if any of them match your hardware.

From here, your best friend is the openHAB documentation at www.openhab.org/docs. You can customize your appliance however you like. It's running Ubuntu Core so you can add Snaps from the repos. Instead of following our later section on Nextcloud, you can get a working install by SSHing into the appliance (the username is the first part of your Ubuntu SSO email) and running:

```
$ snap install nextcloud
```

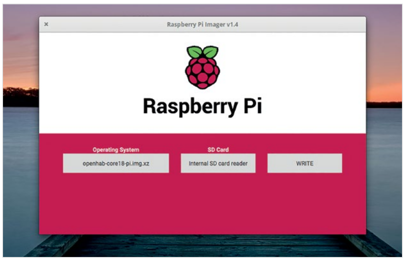
Visit the Snapcraft store (https://snapcraft.io) and let us know how you augmented your appliance. Oh and do check out the others: currently Plex, Nextcloud, Mosquitto, and AdGuard have been applianced, and more will surely follow.

INSTALL OPENHAB



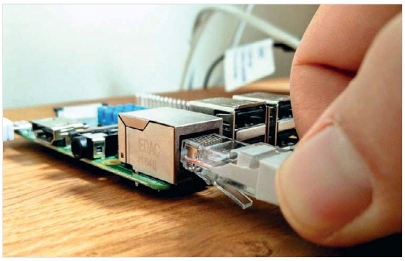
1 DOWNLOAD

Visit https://bit.ly/MPCjanHAB and download the image. It's about 500MB, but compressed. You'll need to decompress it with `xz -d openhab-core18-pi.img.xz` if you're going to write it out manually with dd in the next step, but the official Raspberry Pi Imager program can do this for you.



2 WRITE THE IMAGE TO SD CARD

At least a 4GB card will be required, and possibly more if you go all out with extensions. On a Debian-based distro (including Ubuntu) you can download the Pi Imager from https://downloads.raspberrypi.org/imager and install it with `dpkg -i` or graphically with Gdebi. Use this to write out the image file.



3 BOOT YOUR PI

Connect a monitor, keyboard, and network cable (optional) to your Pi, insert the freshly minted card, and fire it up. You will see some configuration choices and eventually will be asked for your Ubuntu cloud email address (see above) so that the appliance can be authenticated against your SSH keys.

You probably already know that Sherlock Holmes had an older brother called Mycroft—and that's where Mycroft Home Assistant gets its name. The Mark I device was a friendly, ET-looking voice assistant that was powered by a Raspberry Pi 3. We were big fans, but sadly that device is no longer available, and its successor has not yet been released. But that's fine, because Mycroft's brains are open source and can run on a Pi 3 or 4.

BUSTER RHYME

It's based on the official Raspberry Pi Linux Buster image, and you can download it from https://github.com/MycroftAI/enclosure-picroft. Use the Raspberry Pi Imager again (or something else if you like) to write the image to an SD card. This time you'll need at least an 8GB card. When it's done, put the SD card into the Pi and fire it up. As with the openHAB appliance, you'll need a display and keyboard connected to the Pi to run the initial setup, but afterwards these will not be needed unless something goes wrong. On first boot Picroft will resize its partition to use all available space on the SD card. When it finishes booting a second time, it will ask if you would like some help setting up your system, which you may as well accept.

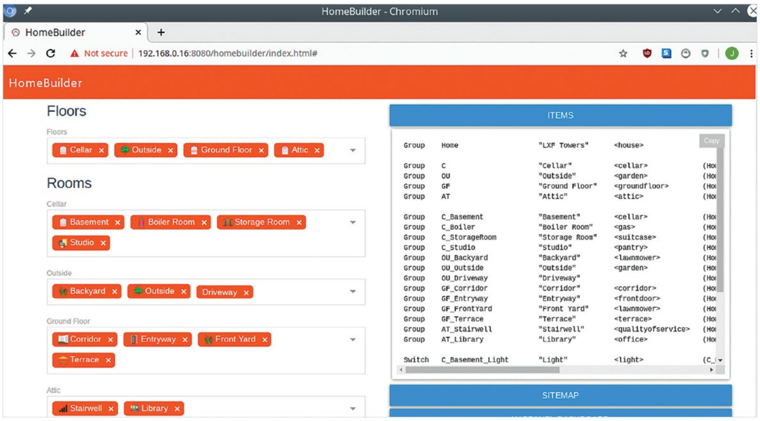
You'll need a microphone and speakers, and there's a list of supported hardware at the Mycroft wiki (https://bit.ly/MPCjanPicroft). Some of this will work out of the box, but some devices will need manual intervention. We used a Seeed ReSpeaker 4-microphone array HAT, which was easy to set up. Other devices will follow a similar pattern. Just run:

```
$ git clone https://github.com/respeaker/seeed-voicecard.git
$ cd seeed-voicecard
$ sudo ./install.sh
```

If your network works (reboot if it doesn't) you can also SSH into the Pi to do this (default username "mycroft" with password "pi," which you should change).

Then, if you're using the 3.5mm jack for audio, you may need to run `sudo raspi-config`, select "7. Advanced Options," "A4 Audio," and finally "1. Force 3.5mm jack." Now reboot to enact the changes. If you run into difficulties with the ReSpeaker (or other Seeed models), the driver documentation is at https://github.com/respeaker/seeed-voicecard.

Reboot, and you can pair your device to the Mycroft Home service. You need to set up an account here to use the software, but hey, at least it's not Facebook. Only your queries are collected, and these are used to better train speech recognition. Just follow the prompts to set this up at https://home.mycroft.ai from another device; if your audio is working you should hear some actual verbiage at this point. If not you can rerun the setup wizard at any time with `mycroft-setup-wizard`.



```
Group   Home                "LXF Towers"     <house>

Group   C                   "Cellar"         <cellar>             (Ho
Group   OU                  "Outside"        <garden>             (Ho
Group   GF                  "Ground Floor"   <groundfloor>        (Ho
Group   AT                  "Attic"          <attic>              (Ho

Group   C_Basement          "Basement"       <cellar>             (Ho
Group   C_Boiler            "Boiler Room"    <gas>                (Ho
Group   C_StorageRoom       "Storage Room"   <suitcase>           (Ho
Group   C_Studio            "Studio"         <pantry>             (Ho
Group   OU_Backyard         "Backyard"       <lawnmower>          (Ho
Group   OU_Outside          "Outside"        <garden>             (Ho
Group   OU_Driveway         "Driveway"                            (Ho
Group   GF_Corridor         "Corridor"       <corridor>           (Ho
Group   GF_Entryway         "Entryway"       <frontdoor>          (Ho
Group   GF_FrontYard        "Front Yard"     <lawnmower>          (Ho
Group   GF_Terrace          "Terrace"        <terrace>            (Ho
Group   AT_Stairwell        "Stairwell"      <qualityofservice>   (Ho
Group   AT_Library          "Library"        <office>             (Ho

Switch  C_Basement_Light    "Light"          <light>              (C_
```

The HomeBuilder UI allows you to build your own virtual MPC Towers, complete with mysterious library.

Once everything's working, the Mycroft CLI client will start, and you can talk and type at it to your heart's content. Shout the magic wakeword "Hey Mycroft" to prick up its digital ears, then try "Tell me a joke," "What is my IP address?" or "How much wood would a woodchuck chuck if a woodchuck could chuck wood?" He likes it when you say "Thank you" too. Responses are again both verbal and on-screen/terminal. You can quit the CLI at any point with `:quit` and then you can run anything you'd run on a normal Raspberry Pi Linux install. If you want to get back into the CLI, run

```
$ mycroft-cli-client
```

There's a custom audio setup script called audio_setup.sh, and don't forget to check the excellent Mycroft documentation at https://mycroft-ai.gitbook.io/docs. Mycroft can be installed on a regular Linux PC either as a Snap Package, through Docker, or straight from its Github. The wake word engine, known as Precise, uses TensorFlow for cutting-edge accuracy, which requires the host to have AVX extensions: Most machines from the last decade will.

POWER AND PRIVACY

There's still a couple of 1st-generation Raspberry Pis keeping things ticking over here at *Maximum PC*. These older models are great—just look at our Pi 2 running Volumio—but lots of projects (such as Mycroft) will require more CPU power, so for a lot of projects you'll see at least a Pi 3 recommended. If you have a Pi 4, you can even run a Jitsi instance that can handle a few callers with no problems. The trouble is, these later models require much more power, so it's important to use a power supply (ideally the official model) that can provide a steady 5.1V supply at up to 2.5A. Cheap USB power supplies can cause all kinds of hard-to-diagnose problems, so if something's behaving oddly, the power is a good thing to check.

Also, we're doing a lot of setting up of web services here, which have the potential to invite the whole world into your machine. So beware of leaving things running with default credentials, and look at firewalling things that only need to run on the local network. You may want to run things in a virtual machine, or on a "disposable" virtual private server to get a feel for them first.

It's your responsibility to maintain these services and keep things up to date too. The journey is far from over once things are up and running. Many companies offerhosted Nextcloud storage, and this may be a better option for small businesses that don't want the burden of administering a server.

JITSI MEET

Set up, secure, and self-host your way to video-conferencing nirvana, and you'll never have to use Zoom again

JITSI MEET IS A FREE, open-source video-conferencing program that you can connect to via a browser or smartphone app. You can use it by visiting https://meet.jit.si and choosing a name for your virtual meeting (or accepting one of the amusing ones the website generates). There's no downloads or configuration required by clients, they just need to click a link that you can share by email from within the meeting room, or dial in and connect with a PIN. Simple.

Obviously Jitsi's free service has some limitations, but these will be gone when you self-host your own Jitsi installation. You don't need any particularly special hardware to do this, and thanks to the excellent Debian and Ubuntu packaging, there's not much in the way of configuration at all. You will need a domain name though; a free one from a dynamic DNS service, such as DuckDNS or DynDNS, will work.

As you can imagine (and we'll look at this in a moment if you can't), under the hood Jitsi is a rather complicated affair. Not only does it have to wrangle the vagaries of streaming through NAT gateways (such as home routers), it also needs to keep all this secure with SSL, so if you cheat and use a self-signed certificate, your users will see scary warnings.

If you're happy for you and your users to see these warnings (or brave enough to add an exception to your browser), and your users are all local, then you can get away with a bogus domain name and fudging users' /etc/hosts files to resolve this to your machine. Or even just use IP addresses directly. But it's probably easier in that case to have an in-person conversation rather than involving the machines. If you have a domain, the install process can automatically generate Let's Encrypt certificates, and then no one needs to see any security warnings.

A Jitsi install is in fact a collection of several components, all working in harmony to bring bright, smiley faces closer in a world that grows ever more distant. Firstly, it relies on a web server (and some pretty wild JavaScript) to provide the web frontend. You can use Nginx or Apache here. Most of the software is written in Java, so keen-eyed dependency spotters will note the OpenJDK runtime making an appearance.

The magic of connecting more than two participants is handled by Jitsi VideoBridge (JVB). This uses the XMPP (like Jabber) and WebRTC (like Google Meet) protocols to swiftly route video to call participants. Deciding which participant is the speaker, and who users see "focused" on their screens, is handled by Jicofo (Jitsi Conference Focus). Note that this is as close to video-processing as Jitsi gets—all the encoding and decoding is handled on the user side. At the heart of it all the Prosody XMPP server keeps all these components and users connected. You'll find more information about these and everything else Jitsi in the handbook at https://jitsi.github.io/handbook.

JITSI? PROBABLY TOO MUCH COFFEE

In order for Jitsi to work for users stuck behind NAT, firewalls, or other obstacles in the stack, XMPP messages and web traffic must be able to flow freely to your server. So you'll need to open UDP port 10000 and TCP ports 80 and 443. TCP port 4443 can be used for fallback communications (if UDP connections are blocked for a user). If you're doing this behind a home router, you'll need to forward these ports.

In an ideal world, one-to-one calls should bypass the JVB, and connect directly to one another (so-called p2p mode), but this may be tricky to negotiate. Prosody can work with a TURN (or STUN) server to facilitate this, but we won't cover this setup here. We will, however, get started with a simple setup after one final warning: The default Jitsi configuration allows anyone to start or join a meeting on your server. If you leave your server running in this way for any length of time, people or bots may discover your machine and can cause trouble. The handbook covers how to set up authentication, which you should do. You should also check the philosophy behind this openness at https://jitsi.org/blog/security. You'll be fine using this guide to get things up and running, but make sure you stop the services when they're no longer needed.

And now we can get on with installation. We're more or less following the Self-hosting Guide in the handbook,

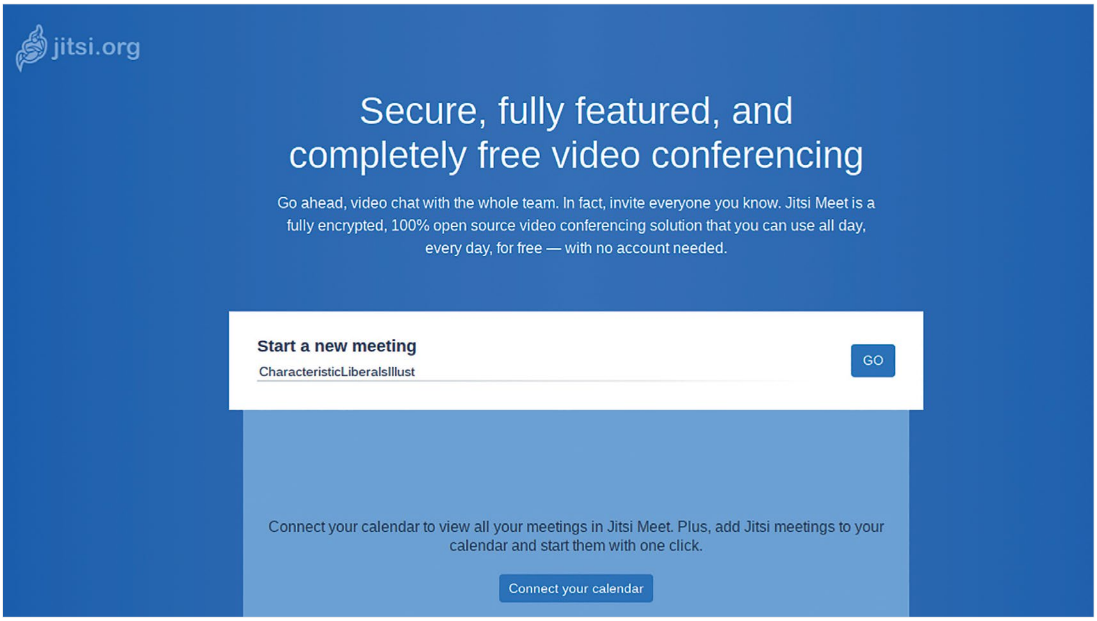
WHAT IF IT DOESN'T WORK?

If you can join a room from multiple locations but don't see any other participants and are stuck with a message telling you you're the only one here, port forwarding is almost certainly the culprit. In some configurations the extra port 4443 will be necessary. Your next stop should be the log files. JVB and Jicofo's are located in /var/log/jitsi and Prosody's is in /var/log/prosody. It's handy to delete these after a configuration change so that you don't get confused by previous logs. Alternatively, use `tail` to view the last few entries. After any configuration change, you'll want to ensure that you restart all the services, which is a matter of:

```
$ sudo systemctl restart jitsi-videobridge2 jicofo prosody
```

You might want to add `nginx` to that list, particularly if you've changed anything that will affect the frontend, such as the authentication you added earlier. And if it all goes wrong you can purge all Jitsi data and configuration with:

```
$ sudo apt purge jigasi jitsi-meet jitsi-meet-web-config jitsi-meet-prosody
jitsi-meet-turnserver jitsi-meet-web jicofo jitsi-videobridge2
```



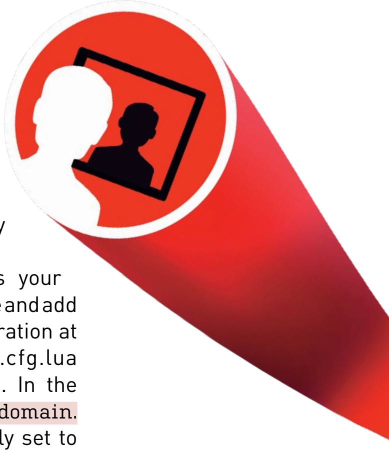
Secure, fully featured, and completely free video conferencing

Go ahead, video chat with the whole team. In fact, invite everyone you know. Jitsi Meet is a fully encrypted, 100% open source video conferencing solution that you can use all day, every day, for free — with no account needed.

Start a new meeting: CharacteristicLiberalsIllust

Connect your calendar to view all your meetings in Jitsi Meet. Plus, add Jitsi meetings to your calendar and start them with one click.

Jitsi is free, easy to use, and its random-name-generation algorithm has been a constant source of amusement throughout these otherwise unamusing times.



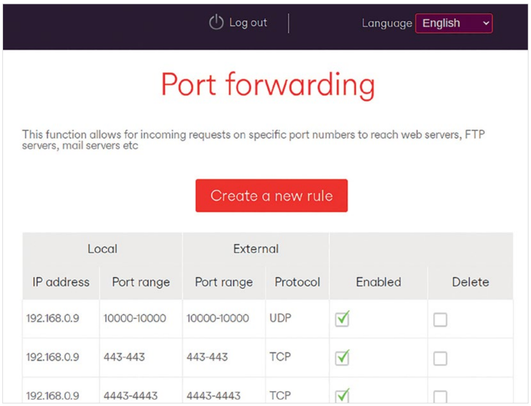
so do check there if you run into any difficulties. First add the Jitsi repo with:

```
$ https://download.jitsi.org/jitsi-key.gpg.key | sudo sh -c 'gpg --dearmor > /usr/share/keyrings/jitsi-keyring.gpg'
$ echo 'deb [signed-by=/usr/share/keyrings/jitsi-keyring.gpg] https://download.jitsi.org stable/' | sudo tee /etc/apt/sources.list.d/jitsi-stable.list
$ sudo apt update
```

Then let the fireworks begin with:

```
$ sudo apt install jitsi-meet
```

During package configuration, you'll be asked for your Pi's hostname, and whether you want to generate a new, self-signed certificate or use an existing one. Choose the first option if you don't already have a valid one for this domain. Replace it with a Let's Encrypt certificate later. At this point, you should be able to log in to your server using your web browser. Just point it to https://meet.yourdomain.com and you'll see the scary certificate warning we warned you about earlier. You can skip this for now (just this once) and you will be greeted by the Jitsi welcome screen, from where you can start a new meeting. Your web browser will ask for permission to use the camera and mic, and you should see a message saying you are the rightful moderator of this room.



Port forwarding

This function allows for incoming requests on specific port numbers to reach web servers, FTP servers, mail servers etc

Local		External			
IP address	Port range	Port range	Protocol	Enabled	Delete
192.168.0.9	10000-10000	10000-10000	UDP	☑	☐
192.168.0.9	443-443	443-443	TCP	☑	☐
192.168.0.9	4443-4443	4443-4443	TCP	☑	☐

If you don't get your ports right, Jitsi will not play nice.

Being alone in a room is no fun, so on another device (or get a friend to do this) visit the meeting by appending a slash followed by the room name to the server's URL.

With that working you can now address your server's slightly too "Open for Business" attitude and add some authentication. Edit the Prosody configuration at /etc/prosody/conf.d/meet.yourdomain.com.cfg.lua (replacing the domain name as appropriate). In the section beginning `VirtualHost "meet.yourdomain.com"` change the authentication line, currently set to anonymous, so that it reads:

```
    authentication = "internal_hashed"
```

Then add (and adjust the domain in) the following at the end of the file to set up a guest domain:

```
VirtualHost "guest.meet.yourdomain.com"
    authentication = "anonymous"
    c2s_require_encryption = false
```

Don't worry, the extra subdomains configured here are only used internally, so they don't need a bona fide DNS record. Now we'll go from Lua to JavaScript and add the guest domain to the front end. Edit /etc/jitsi/meet/meet.yourdomain.com-config.js and add the following lines to the hosts section:

```
    anonymousdomain: 'guest.meet.yourdomain.com',
```

Finally, make focus requests only available to registered users, which is done by editing /etc/jitsi/jicofo/sip-communicator.properties and adding:

```
org.jitsi.jicofo.auth.URL=XMPP:meet.yourdomain.com
```

Now restart the services, and add a user with the `prosodyctl register` command. You can now generate a Let's Encrypt certificate with:

```
$ sudo /usr/share/jitsi-meet/scripts/install-letsencrypt-cert.sh
```

NEXTCLOUD

We've been relying on Nextcloud to keep our files in sync for ages, and we think you should too

NEXTCLOUD JUST GETS BETTER—the latest edition of the self-hosted storage and sharing platform sees it transformed into a complete collaboration hub.

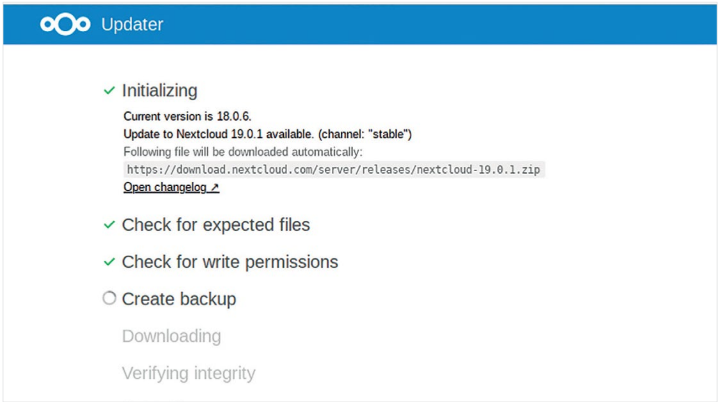
If you already have a LAMP (Linux, Apache, MySQL, PHP) or equivalent stack set up on a home server or VPS, you can easily add a Nextcloud instance to it, either by extracting an archive to your web server's root directory, or by copying the Web Installer PHP file there and running it directly. Setting up a LAMP stack (or indeed a LEMP stack with Nginx and MariaDB) is easy enough (although it's a bit of a faff having to create databases by hand) in Ubuntu or Debian—there are countless guides a mere search away. This time around we're going to install Nextcloud via Docker. In theory this will mean the instance will be portable, so you could go from running on your VPS to running on a home server, or vice versa, with ease. Data and configuration are stored in volumes outside the Docker container (which you should consider a fairly fungible thing), so migrating the service just involves copying those volumes and connecting them to a new instance of the container.

First on the agenda is to install the Docker engine, which requires adding its GPG key to the apt keyring:

```
$ curl -fsSL https://download.docker.com/linux/
ubuntu/gpg | sudo apt-key add -
$ sudo apt-key fingerprint 0EBFCD88
```

You should check that the fingerprint of that key matches the one beginning 9DC8 and given in full in the documentation at https://docs.docker.com/engine/install/ubuntu (where you can also copy and paste these lengthy commands). Next, add the Docker repos (change `focal` to `bionic` if you're using 18.04), update caches, and install Docker with:

```
$ sudo add-apt-repository "deb [arch=amd64] https://
download.docker.com/linux/ubuntu focal stable"
$ sudo apt update
$ sudo apt install docker-ce docker-ce-cli containerd.
io
```



Updater

✓ Initializing

Current version is 18.0.6.

Update to Nextcloud 19.0.1 available. (channel: "stable")

Following file will be downloaded automatically:

`https://download.nextcloud.com/server/releases/nextcloud-19.0.1.zip`

Open changelog ↗

✓ Check for expected files

✓ Check for write permissions

○ Create backup

Downloading

Verifying integrity

If you're already running an older edition of Nextcloud you can upgrade from the comfort of the web interface.

Check that it's working by running the Hello World image, then fire up the Nextcloud image:

```
$ sudo docker run hello-world
$ sudo docker run -d -p 8080:80 nextcloud
```

The first switch tells Docker to run the container detached (in the background), and the second tells it to expose the container's port 80 (where the web server is running) to port 8080 on your server. So now—once a few hundred megs are downloaded and the container springs in to life—if you browse to http://yourserver:8080 (with your address or hostname) you should find the Nextcloud welcome screen. You'll see a warning about the container using SQLite; this lightweight database will be fine for a few users, but more popular setups will need a proper MySQL or MariaDB instance. Go back to the terminal, find your container's name (from the last column of the first command), and stop it with:

```
$ sudo docker ps -a
$ sudo docker stop yourcontainername
```

At this point you could connect Nextcloud to a MariaDB container, and have both store data in named volumes, which will provide portability. The volumes will be available in the /var/lib/docker/volumes/ directory. You can also add boring names to containers.

```
$ sudo docker run -d -p 8080:80 –name nextcloud -v
nextcloud:/var/www/html nextcloud
$ sudo docker run -d -v db:/var/lib/mysql –name
mydb -e MYSQL_ROOT_PASSWORD=secret1 mariadb
```

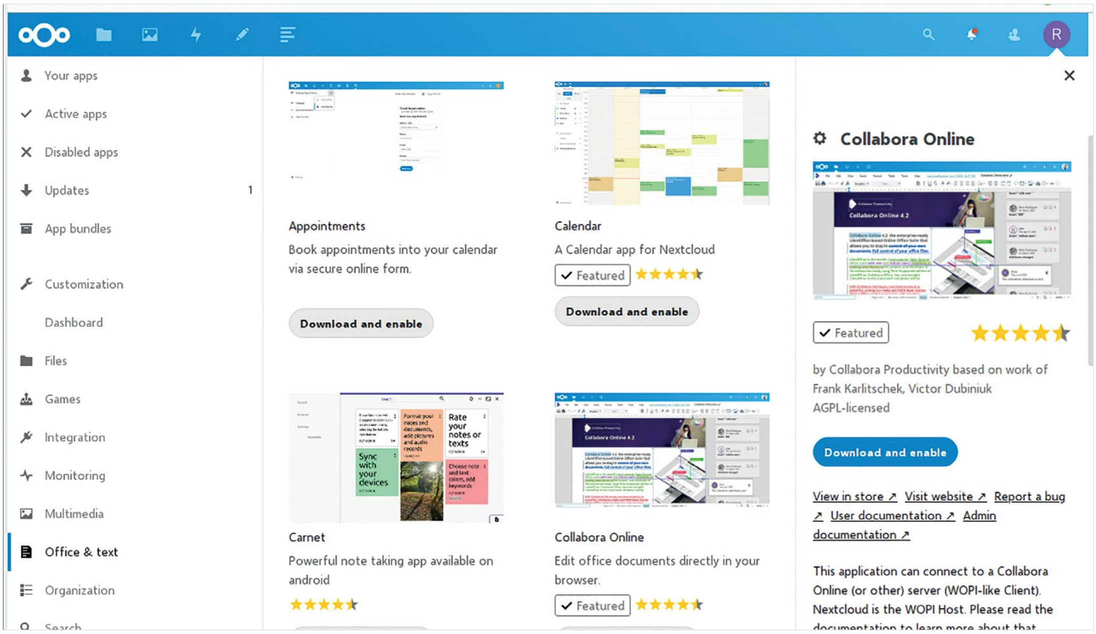
Getting these two containers to talk to each other is tricky, so refer to the Docker Compose section in the documentation, but we'll return to this idea soon. Containers still continue to exist after they've been stopped. Multiple instantiations of the same one aren't a space issue, since the layers of the union filesystem are shared between them. But it's polite to tidy up, so check your containers occasionally with `docker ps` and clear unwanted ones, such as the database above, with:

```
$ sudo docker rm mydb
```

If you want to get rid of everything (danger, beware), you can do so with:

```
$ sudo docker rm $(sudo docker ps -aq)
```

You can at this point go back to the web installer and enter some administrative credentials, doggedly proceeding with the SQLite database, and reusing the first volume. But we're going to borrow from the community and use the example Docker Compose setup, skimming over a few details that you should check in the documentation. Running Docker this way uses four containers, one of which is a reverse proxy running Nginx, which can provide SSL encryption (essential if you make this installation available to the internet at large). Also in this setup is a Let's Encrypt



Appointments

Book appointments into your calendar via secure online form.

Calendar

A Calendar app for Nextcloud

Carnet

Powerful note taking app available on android

Collabora Online

Edit office documents directly in your browser.

Collabora Online

by Collabora Productivity based on work of Frank Karlitschek, Victor Dubiniuk
AGPL-licensed

View in store ↗ Visit website ↗ Report a bug ↗ User documentation ↗ Admin documentation ↗

This application can connect to a Collabora Online (or other) server (WOPI-like Client). Nextcloud is the WOPI Host. Please read the documentation to learn more about that

Jazz up your Nextcloud install with a dizzying array of add-ons. We're big fans of the News app.

host to automatically update certificates. If you've got a domain name setup, the whole thing will be seamless.

Grab the Compose recipe and environment from the Tutorials download, or fetch it from the nextcloud/docker repo on Github. Edit the docker-compose file, setting in particular the MySQL password, the virtual host (your domain name), and Let's Encrypt variables. Follow the official documentation to install Docker Compose at https://docs.docker.com/compose/install, as this process may change. If something doesn't work, peer into the logs of each container, for example:

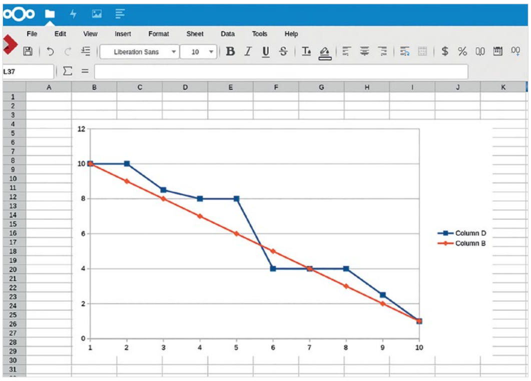
```
$ sudo docker logs compose_proxy_1
```

One way or another, you'll find your way back to the Nextcloud setup screen, and then all further configuration will be free of terminal commands. You just need to choose an admin password, use `db` for the database name (it uses Docker's internal networking so doesn't need a domain name), and wait a few moments for everything to be initialized. Your first step should be to create a new user, which you can do from the "Users" section in the dropdown menu in the top right. It's better to keep the admin account for, well, admin. While you're here, you can use your administrative privileges to see how apps are added to Nextcloud. Select "Apps" from the user menu in the top right, and you'll find a categorized list of them.

It's good practice to keep your containers updated with the command:

```
$ docker-compose pull
```

from the directory with the docker-compose.yml file.



Spreadsheets and charts within web apps and without Google. We're pretty sure Collabora is onto a good thing.

COLLABORA ONLINE

Collabora has just released the latest version of its enterprise edition of LibreOffice: Collabora Office 6.4 (see www.collaboraoffice.com). Alongside that offering is another enterprise release, Collabora Online, which provides an online version of the office suite that can be plugged into a file sync and share host via the Web Application Open Platform Interface (WOPI).

A free version of Collabora Online—the Development Edition, aimed at home users—is available, and it can be connected to your Nextcloud instance to provide functionality not entirely dissimilar to Google Docs.

The easiest way to set it up is to use the Docker image and follow the instructions at https://nextcloud.com/collaboraonline. The CODE docker image listens on localhost:9980, so for this to be accessible to the outside world the instructions should use an Apache reverse proxy. It's recommended to have this proxy run on a different domain (the same machine is fine) to your Nextcloud host, which is a little complicated because for this to work smoothly you need to have valid SSL certificates for both.

It's possible to use the same domain (at a cost to security), or self-signed certificates, but you may have to be creative in your approach here. Once you've done the hard work, install the Collabora Online app using your Nextcloud admin account, and then configure it with the domain where the proxy is listening.

We haven't heard the term "groupware" since Novell Netware, but we're glad Collabora is bringing back the term with such style.

PORTAINER & DOCKER

Contain your sprawling smart home office with Portainer, then ruminate on a fully featured email server with Mailcow

WHEN YOU'RE RUNNING a home server or VPS, Docker is pretty great because you can add services without messing (too much) with the underlying system configuration. As we've seen with Nextcloud, though, even with just four Docker containers things become unwieldy. Portainer is a Docker management system that aims to restore order.

It comes in two parts—server and agent—which both ship as Docker containers. you'll only need the server image for this initial foray. The agent is used to marshall Docker Swarms, which are another way of connecting containers together. Let's start by creating a volume for data, and then firing up the image.

```
$ docker volume create portainer_data
$ docker run -d -p 9000:9000 --name=portainer
--restart=always -v /var/run/docker.sock:/var/run/
docker.sock -v portainer_data:/data portainer/portainer
```

Note that images can be added according to their listing on Docker Hub, so you can find out more about the Portainer image at https://hub.docker.com/r/portainer/portainer. You should find Portainer's admin panel now waiting for you on port 9000, so point your browser there, choose a password, select "Manage the local Docker environment" and enjoy the friendly interface. If you installed Nextcloud through Docker earlier, you should see all those containers listed in "Local Endpoint" on the Home screen. If you click "Containers" on the menu on the left, you'll see these (and our latest Portainer container) in more detail. The quick-actions column allows you to see each container's logs, info, stats, and log in to each one directly from the browser. This is a great way to do some troubleshooting, but recall that containers in general are quite minimal, so you won't find any fancy utilities.

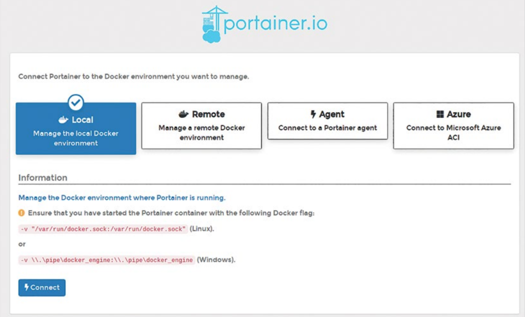
Adding a new container is easy. For example, if you want to add Collabora's CODE, and connect it with a Nextcloud install, hit the "Add Container" button and enter a meaningful name. In the "Image" field enter `collabora/code`, and in the "Manual network port publishing" section enter `127.0.0.1:9980` in the host field and `9980` in the container field. In the "Advanced" container settings below, go to the "Env" section and set the following environment variables:

```
domain: share\\yourdomain\\.com
username: admin
password: yourpassword
```

Finally, in the "Restart policy" column select "Always," so the container restarts upon configuration change. Hit "Deploy," and the container will spring into life. For guidance connecting it to your Nextcloud instance, check the documentation at https://nextcloud.com/collaboraonline. All going well, you should be able to specify it from Nextcloud, specifically from the "Collabora Online" section in "Settings." You may need to tweak the reverse-proxy container to direct traffic to the new container, if you used the Docker Compose example on the previous page.

In that case you'll find that example in the "Stacks" section with a warning about it being created outside Portainer. In Portainer parlance, groups of containers are called Stacks, and it can only do limited things with externally created Stacks. However, it's easy to create a new Stack; just paste, upload, or point Portainer to the URL of a docker-compose.yml file.

Nextcloud's own groupware—its Calendar, Talk and Mail applications—can be used for collaboration among


portainer.io
Local
Manage the local Docker environment
Remote
Manage a remote Docker environment
Agent
Connect to a Portainer agent
Azure
Connect to Microsoft Azure ACI
Information
Connect

Connect Portainer to the Docker environment you want to manage.

Manage the Docker environment where Portainer is running.

Ensure that you have started the Portainer container with the following Docker flag:

`-v "/var/run/docker.sock:/var/run/docker.sock"` (Linux).

or

`-v \\.\pipe\docker_engine:\\.\pipe\docker_engine` (Windows).

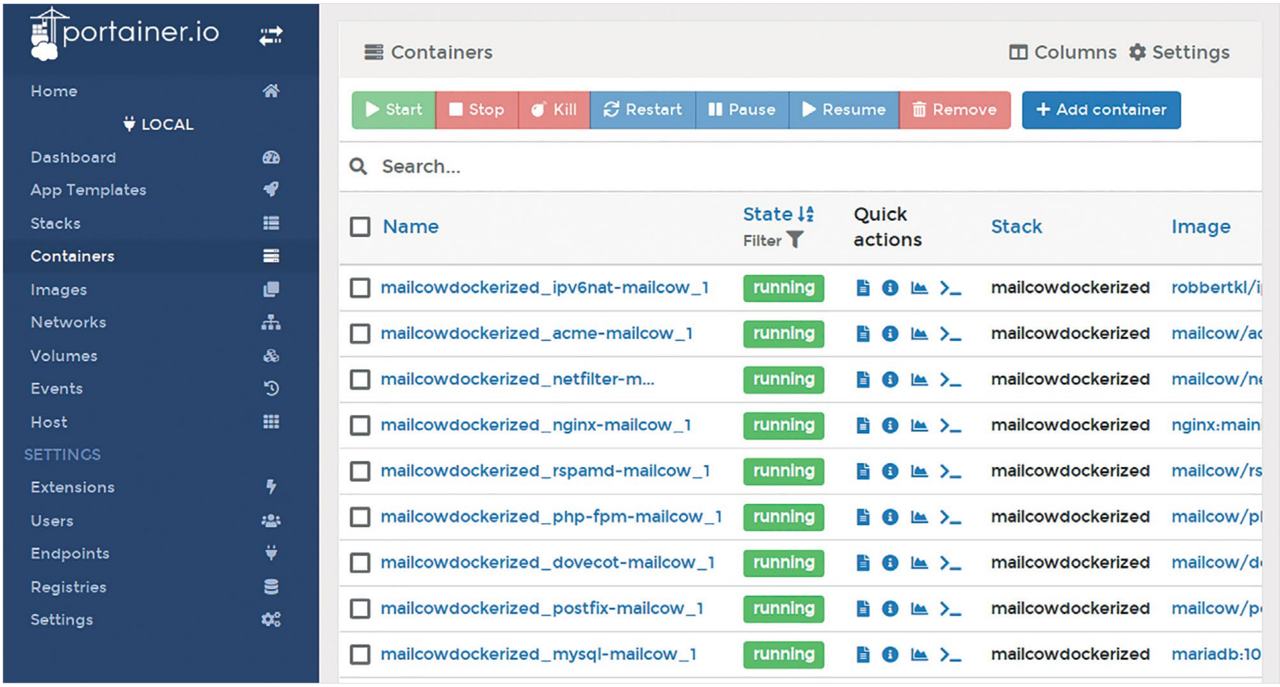
Besides running locally, Portainer can be used to manage remote systems running its agent.

JITSI PI IN THE SKY/CLOUD

If you're feeling adventurous, it is possible to install Jitsi Meet on a Raspberry Pi 4 with 4GB (the 8GB version will perform better though). This isn't officially supported and setup is a little complicated. Also our Pi 4s are all locked up in our offices until such time as it is deemed COVID-proof.

We were feeling extravagant so we took advantage of Mythic Beasts' commitment-free, per-second billing and rented ourselves a remote Pi 4. Mythic Beasts' offerings use PXE booting and mount the root filesystem via NFS from their own storage arrays. This means you're not at the mercy of unreliable SD cards, and also allows you to rent up to 250GB of storage. We were more frugal, however, and went with the minimum 10GB.

If you're setting up Jitsi on your own Pi locally you might have to do a little detective work (or plug in a monitor) to find your Pi's IP address on your LAN. And if you use Mythic Beasts' offering be aware that its Pi servers are connected by IPv6 only. A gateway is available so that IPv4-only users can still connect to it, but you'll need a real DNS record (DuckDNS doesn't count here) to use it for anything other than as a standard web host. We were a bit embarrassed that it took us a while to figure this one out.


portainer.io
Home
LOCAL
Dashboard
App Templates
Stacks
Containers
Images
Networks
Volumes
Events
Host
SETTINGS
Extensions
Users
Endpoints
Registries
Settings
Containers
Columns
Settings
Start
Stop
Kill
Restart
Pause
Resume
Remove
Add container
Search...

☐ Name	State Filter	Quick actions	Stack	Image
☐ mailcowdockerized_ipv6nat-mailcow_1	running		mailcowdockerized	robbertkl/i
☐ mailcowdockerized_acme-mailcow_1	running		mailcowdockerized	mailcow/ac
☐ mailcowdockerized_netfilter-m...	running		mailcowdockerized	mailcow/ne
☐ mailcowdockerized_nginx-mailcow_1	running		mailcowdockerized	nginx:main
☐ mailcowdockerized_rspamd-mailcow_1	running		mailcowdockerized	mailcow/rs
☐ mailcowdockerized_php-fpm-mailcow_1	running		mailcowdockerized	mailcow/p
☐ mailcowdockerized_dovecot-mailcow_1	running		mailcowdockerized	mailcow/d
☐ mailcowdockerized_postfix-mailcow_1	running		mailcowdockerized	mailcow/p
☐ mailcowdockerized_mysql-mailcow_1	running		mailcowdockerized	mariadb:10

Mailcowdockerized involves about 20 containers, but you can disable a few of them. Great again.

users. The Mail app is just a client, so set it up with a provider as you would in a desktop email client. It's often been said that setting up an email server properly is hard. This is true, but you can set up a rough-and-ready container running Postfix, Dovecot, and Roundcube and have a working (but not necessarily well-configured) email setup in just a few keystrokes thanks to the Mailcowdockerized image.

Setting this up might offend the sensitivities of those adverse to running things as root, but the image uses extended attributes and requires it. So let's be a superuser and check that our umask is set correctly (it should print 0022).

```
$ sudo -i
# umask
```

Now we'll clone the repository into /opt:

```
# cd /opt
# git clone https://github.com/mailcow/mailcow-dockerized
# cd mailcow-dockerized
# ./generate_config.sh
```

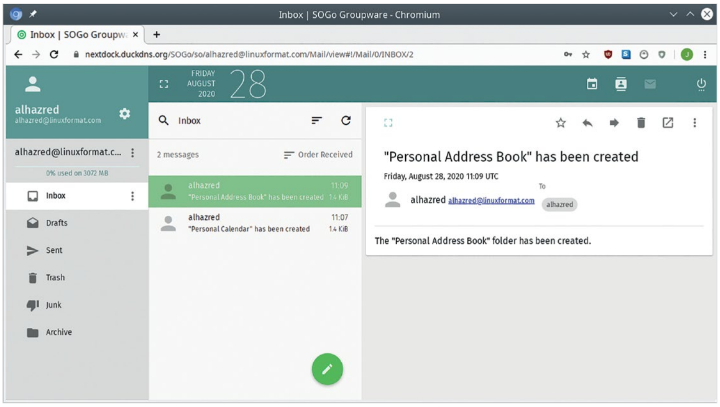
You'll be asked for your domain name; this is the host that it's running on, not the domain of any email addresses you want to set up. If your machine has limited memory, the script will suggest that you disable Solr (the heavy-duty Java search platform), which you should. The script generates mailcow.conf, which you may wish to tweak. We'll just plough right ahead. First, in case they get in the way, stop Nextcloud and any other containers now. In Portainer, do this by choosing "Containers" from the menu on the left, selecting all of them except Portainer (because that would be silly), and pushing the stop button. There's a "Kill" button next to it in case they don't shut down gracefully, and you can also remove them entirely if you don't like them.

Now return to the terminal (still using the root account) and let's fetch and unleash the Mailcow:

```
# docker-compose pull
# docker-compose up -d
```

At this point, you technically have a working mail server. You should be able to log in from the web interface, using the credentials `admin:moohoo`. But there's still a lot of configuration to do, not least changing that password: Click "Edit" next to the admin user. If you want to receive mail you'll need to properly set up MX records for your domain(s) with your DNS provider, otherwise mail won't be routed correctly.

Then you can configure them from Mailcow's "Domains" section, and can configure the addresses in the "Mailboxes" section. In a world of spam, do your bit by enabling DKIM (Domain Keys Identified Mail), which signs messages originating from your server. DKIM-enabled servers will verify this key when they receive mail from your domain, preventing malfeasance. ⏻


Inbox | SOGo Groupware - Chromium
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nextdock.duckdns.org/SOGo/so/alhazred@linuxformat.com/Mail/view#!/Mail/0/INBOX/2
FRIDAY
AUGUST
2020
28
alhazred
alhazred@linuxformat.com
Inbox
alhazred@linuxformat.c...
0% used on 3072 MB
2 messages
Order Received
Inbox
Drafts
Sent
Trash
Junk
Archive

alhazred 11:09
"Personal Address Book" has been created 1.4 KiB

alhazred 11:07
"Personal Calendar" has been created 1.4 KiB

"Personal Address Book" has been created

Friday, August 28, 2020 11:09 UTC

alhazred alhazred@linuxformat.com To alhazred

The "Personal Address Book" folder has been created.

Once you've set up your mailboxes, you and your users can log in to the SOGo webmail client by adding /SOGo to Mailcow's domain name.

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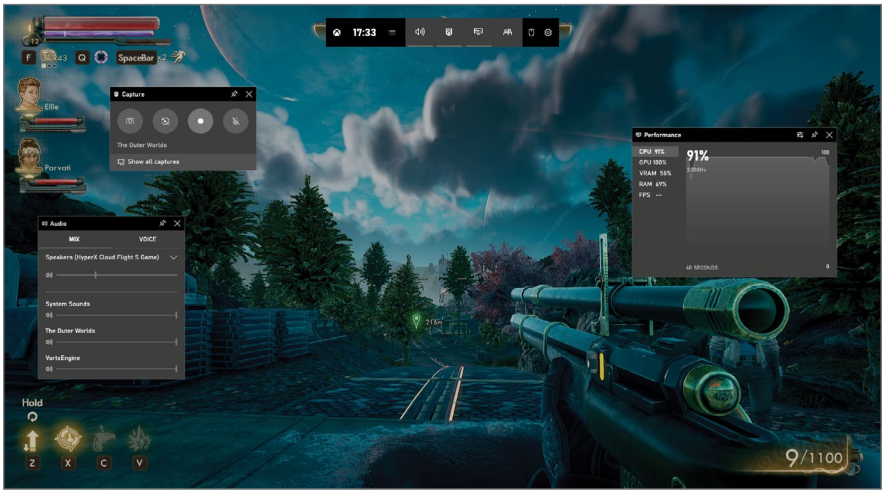
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

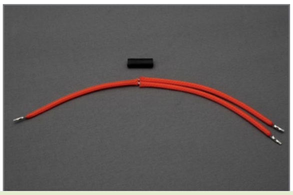
TIP OF THE MONTH


17:33
SpaceBar
Ellie
Parvati
Capture
The Outer Worlds
Show all captures
Performance
CPU 91%
GPU 100%
VRAM 58%
RAM 69%
FPS --
91%
60 SECONDS
Audio
MIX
VOICE
Speakers (HyperX Cloud Flight S Game)
System Sounds
The Outer Worlds
VortexEngine
Hold
Z
X
C
V
9/1100

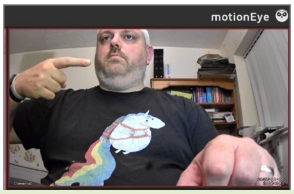
GIVE THE GAME BAR A TRY

Windows 10's support for gamers has been steadily improving over the years. Hit Windows + G to access a suite of handy features, such as capture tools, customizable integrated widgets (including stuff like Spotify or Asus's ROG Armory Crate), and live system monitoring. You can even snapshot the previous 30 seconds of footage, perfect for saving those "pro gamer moments," as the kids call them.

MAKE – USE – CREATE



56
Cable sleeving part three: make your own Y cable



58
Make security cameras with motionEyeOS

64
We build a full-tower super storage station

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CHRISTIAN GUYTON
STAFF WRITER

A NEW DAWN COMETH

By the time you read this, it will be 2021, with the nightmarish year of 2020 behind us. I'm writing this from the tail end of the year, and taking a moment to reflect really drives home quite how many crazy events the universe has managed to pack into 365 days. Yes, I'm sure things will be turbulent this year too, but if there's one good thing to come out of 2020, it's the tech.

COVID, wildfires, and political carnage aside, it's been a great year for PC hardware. Both Nvidia and AMD smashed records with their new powerhouse GPUs, finally making 4K 60fps a truly viable option, and offering a tantalizing glimpse into a glorious future of 8K gaming. The framerate-battering "benefits" of ray-tracing also seem to have fallen by the wayside a bit, to which I say good riddance.

AMD's spicy Ryzen 5000 chips are also dominating benchmarks, and PCIe 4.0 has set a new gold standard for drives that might finally be sowing the first seeds of doom for HDDs. I'm also still eagerly awaiting Intel's venture into the graphics card market with its Xe GPUs.

Whatever happens in 2021, I'd just like to say that it's been an honor to write for you all here at *Maximum PC*, and I hope you're just as excited as I am to see what cool tech this new year has to offer.

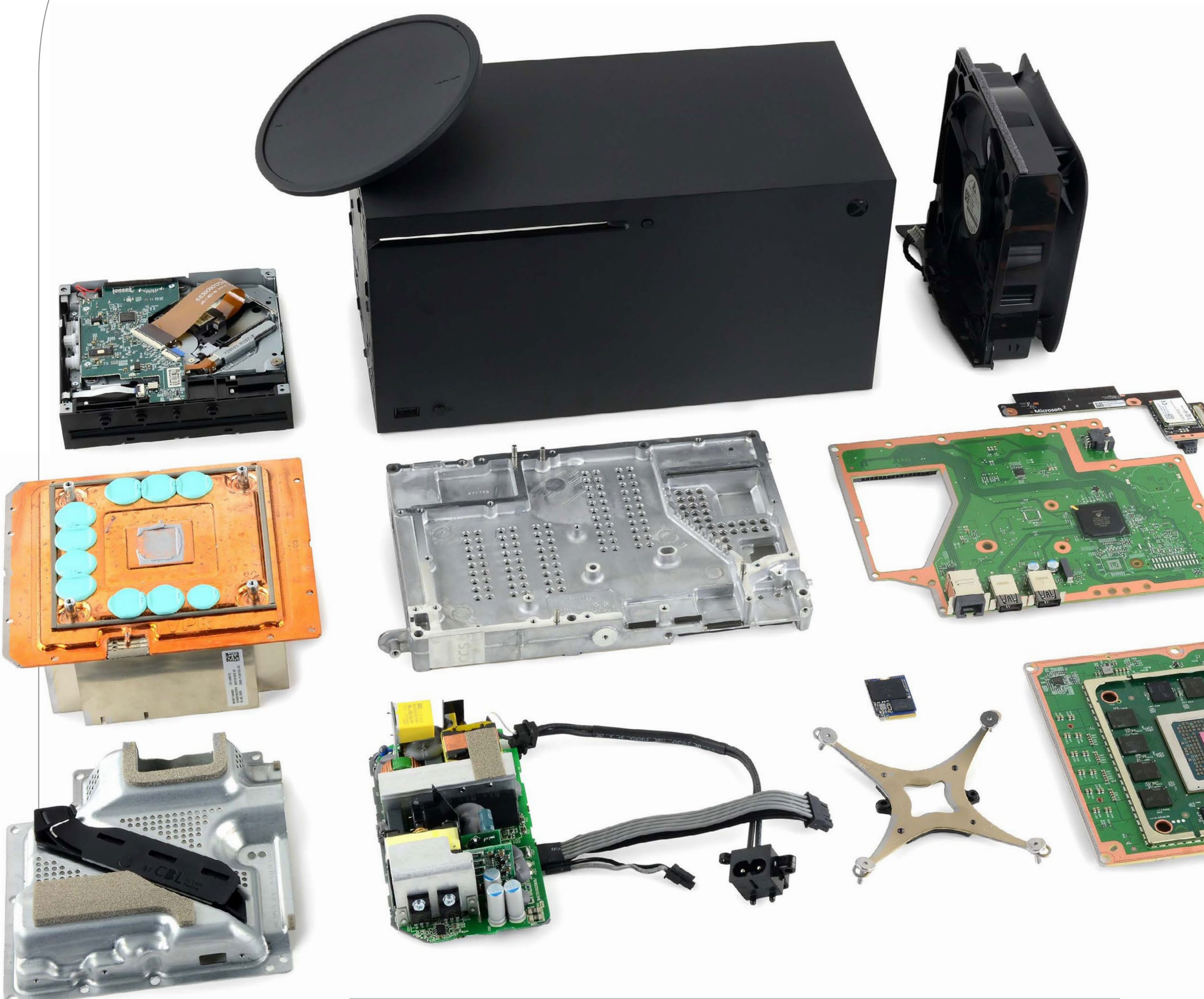
↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

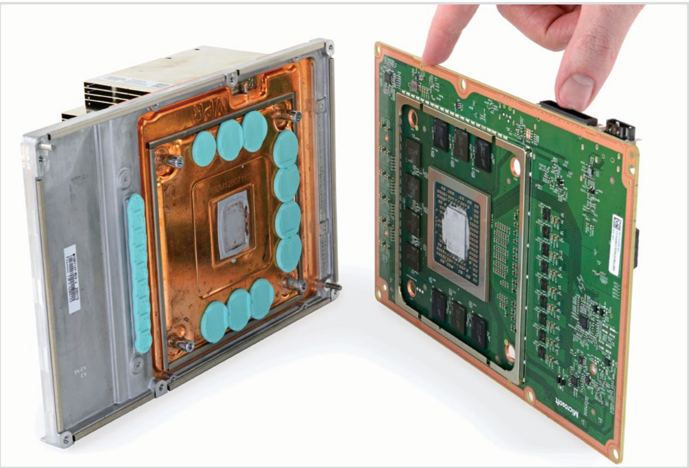
Xbox Series X

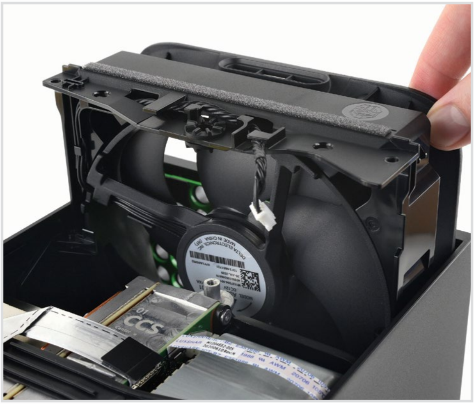


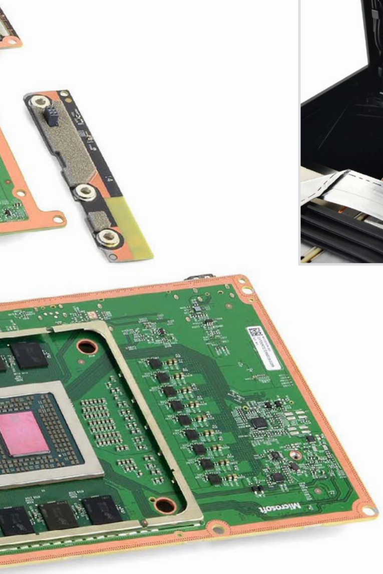
About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.

The name might not be all that different from the last gen, but everything else is.



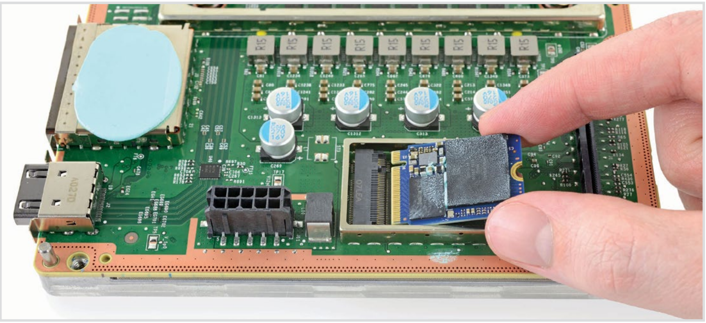




Above Top: **This thing is starting to look ever so similar to those GPUs *Maximum PC* is always taking apart.**

Above: **Similar to the Corsair Ones, Microsoft is using a single fan to cool the entire machine.**

Below: **Featuring PCIe 4.0. this bespoke WD drive should be fast enough, shame it's not easily replaceable.**



BACKGROUND

Buried in a blizzard of buzzwords like "teraflops," "true 4K," and "ray tracing" is a new device—Microsoft's statement on gaming for the next several years. It's teardown time.

MAJOR TECH SPECS

- AMD custom 8-core 3.8 GHz (3.66 GHz with SMT) Zen 2 CPU
- AMD custom RDNA 2 GPU (1,825 MHz with 52 Compute Units)
- 16GB GDDR6 RAM
- 1TB SSD storage (with an optional 1TB Expansion Card)
- HDMI 2.1 connectivity with support for 8K video at 60 Hz, or 4K 120 Hz
- 4K UHD Blu-ray drive

KEY FINDINGS

- This year's flagship Xbox is rocking a fuller figure and serious cooling. More grilles grace the back of the console, along with the usual ports and a new storage expansion slot. The ports come with some tactile identification in the form of tiny raised dots, making the finding-and-plugging process easier.
- Two bright green T8 screws suggest an official Xbox welcome into the machine, yet those screws are hidden under stickers and a trapdoor. Regardless, it won't stop anyone armed with our Mako driver kit. Spin the driver, pop a few clips, and in. We've got our crosshairs dialed in. Primary removal target? The beefy 130mm fan. It's pretty get-at-able for cleaning—a big plus. If your X stands up tall, this is upward exhaust.
- Microsoft hasn't wasted any space inside—check out how much volume is dedicated to the heatsink. It's clear the Series X is built to run cool and quiet. Mounted up front is one of two antenna boards inside the tower. The redundancy might serve to ensure a solid connection in either of the console's two orientations: Tower mode, and awkward mode.
- Moving along to a box within the box, we lift the power supply away from the main assembly. This PSU's primary rail outputs up to 21.25 amps at 12 volts, which equates to 255 juicy watts. Add the peripheral 60W output, and you get a total of 315 watts. The supply uses pricier, longer-lasting polymer capacitors instead of electrolytic ones to filter the 12V output.
- The Series X uses an M.2 2230 NVMe SSD, namely a custom 1 TB SN530 by Western Digital. We heard it's super-fast PCIe Gen 4.0, too. It's nice to see Microsoft using a replaceable drive here, even if software barriers prevent you from doing the replacing. Since this SSD comes in a standard M.2 form factor, we popped it into our desktop workstation for a peep at its contents. If you were expecting it to be partitioned a lot like the hard drives found in prior Xboxes, you're way ahead of us. Even though the SSD itself is fairly standard, if past experience is any guide, plan on some serious headaches if you ever need to replace or upgrade it in the future.
- It almost feels like an air conditioner with a graphics card. A relatively modular and repair-friendly design is overshadowed by some software barriers. Our tests indicate that both optical drive and SSD repairs will be problematic.
- Xbox Series X Repairability Score: 7 out of 10 (10 is easiest to repair). Very few tools are needed to disassemble the console. All screws are standard T8 Torx fasteners. The modular design allows for easy fan, optical drive, PSU, and wireless board replacements. The SSD is a modular, off-the-shelf part, but requires a bit of disassembly to access. Some critical component repairs are complicated by software locks. ⏻

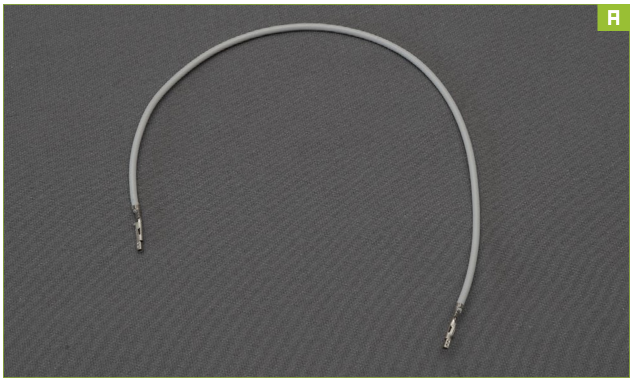
Cable Sleeving Part 3: Y Cables

YOU'LL NEED THIS

TOOLS OUTLINED IN PREVIOUS ISSUES
Soldering equipment
Heatshrink
Sleeving
Craft knife or similar
Crocodile clip/ Helping hands

IN THE LAST TWO ISSUES we have been showing you the tools of the sleeving trade, and how you can sleeve your own custom power-supply cables. And with this new-found knowledge you should be able to create a set of cables or extensions, as long as they don't have any "Y" cables involved in them at all. Y cables are most commonly found on the 24-pin ATX motherboard power cable, and can be a little bit trickier, but once you know how to do them, you can have that perfectly sleeved PSU that you absolutely deserve.

This is gluttony when it comes to building your own system, and it can take time and patience to get the job done right, but once it's done, you'll truly have a bespoke system that's unique to you. Whether you're big into air cooling or liquid cooling, jazzing up the cables like this really brings a build to life and gives it a personalized feel. So let's get started. **–DAVE ALCOCK**



1 MEASURE AWAY

To start making a dual wire or Y wire, you'll need to measure the route between the PSU and the component being powered. Using a bit of wire or string works, but do make sure to remember that the sleeving adds to the mass of the wire, so you will need to account for that in its length. While you're measuring the wire, make a mental note of how much wire is behind the motherboard tray. You're going to use the motherboard tray to hide the join of the wires and the ugly bit of the cable.

2 CRIMP IT

Once you have the length, crimp the terminals to the cable like you usually would. Remember that the locator pins go into the connector facing the click on the connector. This is handy to know, as you can use the natural curve in the wire to create this beautiful arc, and it is particularly useful when making dual wires as you can determine the orientation of the cable better. You don't want to be fighting the wire at any point during this process. [Image A]

3 RAMPING UP

Once you find an area that will be hidden, you will need a sharp knife, such as an exacto knife or similar. First, you want to slice half of the insultion from the wire. It doesn't have to be a long section: 5-10mm will be fine.

» Next, leading up to the now-exposed wire, you want to create a little ramp in the insulation down to the wire. The location of this ramp matters, however. If you want wires on top of each other, for example for the ground pins on an eight-pin PCIe cable, then you want the ramp on top of the cable like we have shown here. If you want the cables to be side by side, for example a 24-pin cable, you will want the ramp and exposed wire on the left/right side of the cable. This just means that you're working with the cable rather than against it. It will become second nature after a while. [Image B]

4 DOUBLE THE FUN

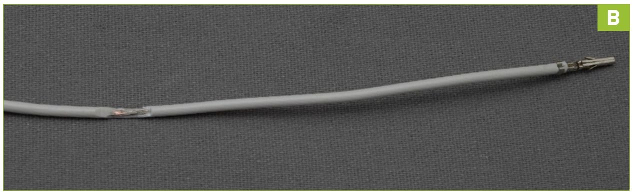
Once you have this single cable prepped, it is time to introduce the second cable. Again, crimp it as per usual, and then on the other end you want to just strip the same length of insulation from it as you removed from the other wire. These two wires are going to be soldered together. Again, you want to create a little ramp leading up to the removed insulation so that the two wires fit together snugly. The longer the ramp, the nicer the fit. [Image C]

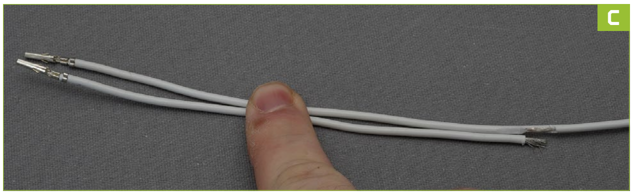
5 SOLDER ON

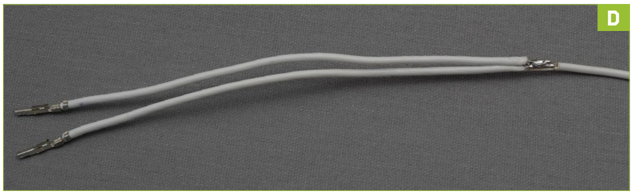
Once you've done this, it is time to get the soldering iron out. Don't worry, you don't need to be a professional here, just knowing which end is the hot one is usually enough. Use some flux on both the parts that are going to be soldered. Tin the wires so that they have a light coating of solder on them. If you have one available, use some helping hands or a crocodile clip to hold the wires together. Don't worry if you don't have any available, you can do it with your fingers, but be careful! Now just use the soldering iron to melt the solder that is already on the wires. You really don't need much solder here, but if you do need to introduce more, try not to overheat the wire and melt the insulation. [Image D]

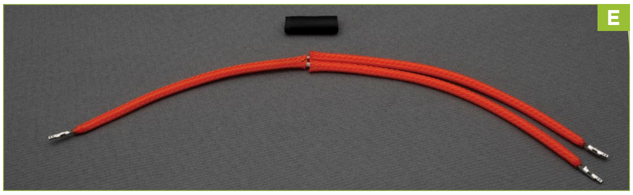
6 Y SLEEVE

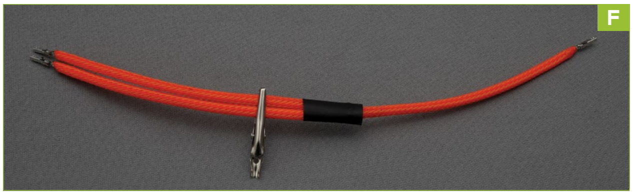
You have made a Y cable! Yay! Now it is just time to sleeve it. This will be easier if you have already mastered the single cables. You want three pieces of sleeve that all meet in the middle. At the terminal end the sleeving should sit between the first and second flag as per usual. Remember that sleeving stretches though, so although our picture [Image E] shows what it should look like on the wire, there is a little more sleeve than needed and we'll trim it down before adding it to the wire.

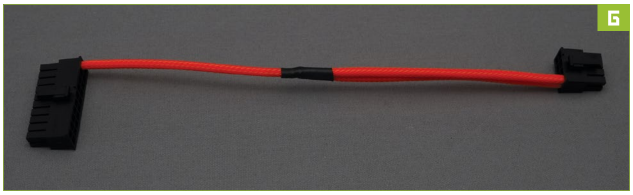












›› Using the same method as we showed in part two of our tutorial, sleeve the terminal ends so that the sleeve all touches nice and neatly in the middle. Once you have done this you will want a length of heatshrink that will cover the join completely. I usually use around one inch.

7 TIME TO HEATSHRINK

Push the heatshrink over the double-wire end—trying to get the wire over the dual wires from the single-wire end is considerably more hard work. Now you want to tighten the sleeve so that it looks uniform. Once again, if you have a crocodile clip, use it here as you have to try and hold three sleeved wires, as well as a lighter. Hit the heatshrink with your lighter, making sure that you start to melt the sleeve inside the heatshrink, but that you don't burn the shrink itself. If you do burn the heatshrink, simply put a second piece over the top of it to make it look prettier. [**Image F**]

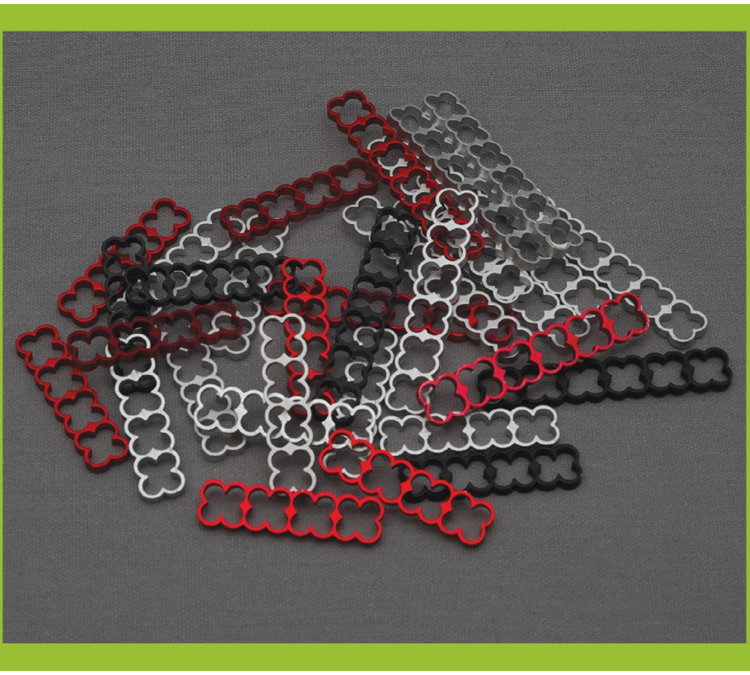
8 SUCCESS FEELS GOOD

And that's it, you have successfully made and sleeved a Y cable! Now you just have to push it into a connector and do all the other cables you need to make. [**Image G**]

›› Making cables is a long-winded affair, and it does take patience, asbestos hands, and some brain power. However, it is so rewarding when you get a perfect set of cables, and without making them by hand or getting someone else to make them to your exact specifications, you will never get a achieve a style of PC that we strive so much to get.

CABLE COMBS

If you make the perfect cables, you won't need to use cable combs, but if you are buying aftermarket cables, or if you simply like the look, you can get many shapes, sizes, and colors. The two main types are open combs and closed combs. Open combs, as the name suggests, are open, and you can simply slide them between the two rows of wires and make them look neat after they've been sleeved. Open combs are usually chunkier and don't look as aesthetically pleasing. The other type of cable combs are closed combs. These are trickier to fit, as you need to remove the wires from the connectors. Now you have our handy guide, though, you know what tools you need for this and how to do it. We like to remove one wire at a time and slide it through the cable comb to ensure that we don't get anything mixed up. Closed cable combs look far prettier and less intrusive, so knowing how to fit them is really handy.



Make Security Cameras With motionEyeOS

YOU'LL NEED THIS

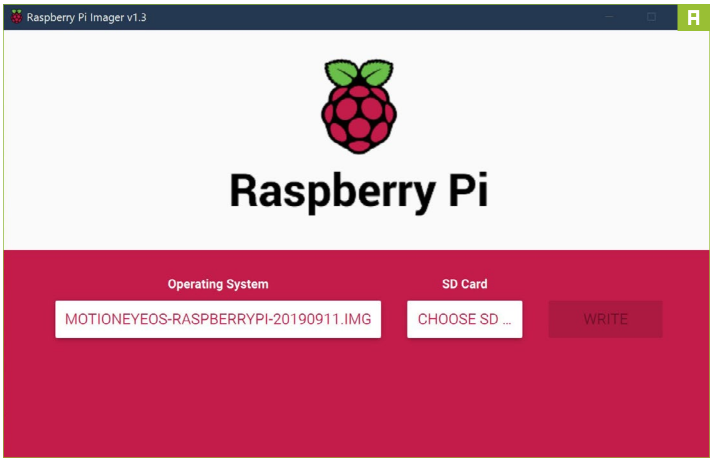
A SINGLE-BOARD COMPUTER
Compatible camera(s). A microSD card.

MOTIONEYEOS

GIVE A PERSON A CAMERA, and they'll find a way to point it at other people. Most of the single-board computers that are popular at the moment have camera attachments, or can use a webcam through a USB port. MotionEyeOS is an operating system that does nothing but operate cameras, and it can be installed on a great many of these boards—we're using a Raspberry Pi Zero W, but Banana Pi, NanoPi, ODROID, and Pine boards are all compatible.

MotionEyeOS is a lightweight way to run motionEye, the web interface that gathers together the feeds from connected cameras and displays them, running motion-detection routines and triggering recordings or stills when motion is detected. It can take feeds from connected cameras or network cameras, and multiple boards can work together as individual cameras or hubs.

The whole thing is the work of Calin Crisan, a developer who has also taken the time to write a wiki detailing the installation and usage of the OS on its Github page. There's a lot more going on than we can cover in this simple tutorial, so if you want to make a complex surveillance system relatively cheaply, this might be a good way of going about it. **–IAN EVENDEN**


A

Operating System: MOTIONEYEOS-RASPBERRYPI-20190911.IMG

1 SET UP YOUR HARDWARE

We're using a 16GB microSD for this, but any capacity will do. Download the motionEyeOS from https://github.com/ccrisan/motioneyeos/wiki, and the Raspberry Pi Imager from https://www.raspberrypi.org/software/. Install the app on a Windows PC (or a Mac, or Ubuntu) and use it to install the OS from its ISO to your SD card [**Image A**]. To get the Pi to connect to your network, you have a choice: You can connect a USB-to-Ethernet adapter via the microUSB port and connect it to a wired network, or you can preload it with your Wi-Fi details. When it's finished, pop the card out, then put it back in again—in Windows, you'll probably get an error saying your card needs to be formatted, but don't press "OK"—the FAT32 partition will mount and be readable. Open this from This PC, and use something like Notepad++ (Windows's built-in Notepad doesn't format the lines correctly) to create a new text file in the root directory with the name "wpa_supplicant.conf"—remove any .txt extensions. This information enables the Pi Zero to connect to your Wi-Fi. The content of the plain text file should be this:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
country=[your country in two letters,eg: US]
update_config=1

network={
ssid=["Network"]
psk=["Password"]
}
```

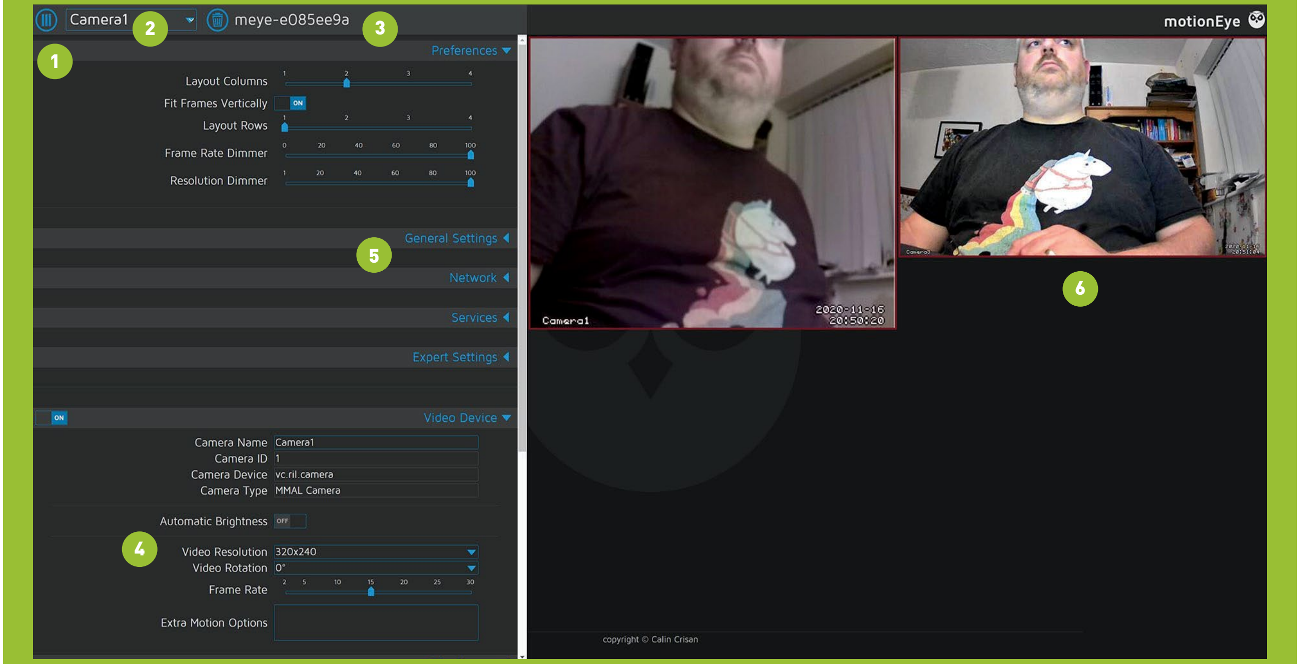
» In Notepad++, set the EOL conversion to UNIX LineFeeds ("Edit → EOL Conversion → Unix LF"). This is important, because without a properly formatted file the Pi won't read it, won't be able to find a network, will put up unhelpful error messages involving the word "panic," and will restart in a loop. When you've saved the file, pop the microSD card into the Pi Zero, clip it into its case (we find it easier to handle the tiny board when it's in a case), and attach the HDMI and USB adapters, plus the camera on its flex cable. Be careful when plugging the camera in, as the camera for the Pi Zero comes with a thinner and more easily torn ribbon cable, and its camera port is quite tight.

OTHER OSES

If you don't want to turn your board into a dedicated camera system, it's possible to install motionEye, without the OS, on other operating systems. Many flavors of Linux can take it, including the Raspbian (now called Raspberry Pi OS) distribution that powers the Raspberry Pi boards (make sure you enable the camera module in Raspi Config if you're going to use one). It has all the same features as the OS version, including the ability to carry the feeds from network cameras, something we didn't explore in the main tutorial. Running on a more powerful PC, motionEye could detect motion from a number of network cameras scattered across a property but within Wi-Fi range of a router or hotspot, with the web interface always available in the user's browser. You can even install it in Docker.

© RASPBERRY PI FOUNDATION

THE INTERFACE



Camera Name: Camera1
Camera ID: 1
Camera Device: vc.ril.camera
Camera Type: MMAL Camera
Automatic Brightness: OFF
Video Resolution: 320x240
Video Rotation: 0°
Frame Rate
Extra Motion Options

1. THREE LINES
Click here to get to all the options for the operating system. Without the menu open, the camera feeds completely fill the interface.

2. CAMERA MENU
Drop this menu down to find options to add a camera, select an existing one, or use the trashcan button to delete one of the cameras.

3. ID NUMBER
This is the ID of your motionEyeOS installation. Look out for it on the local network, as it will designate your Samba share.

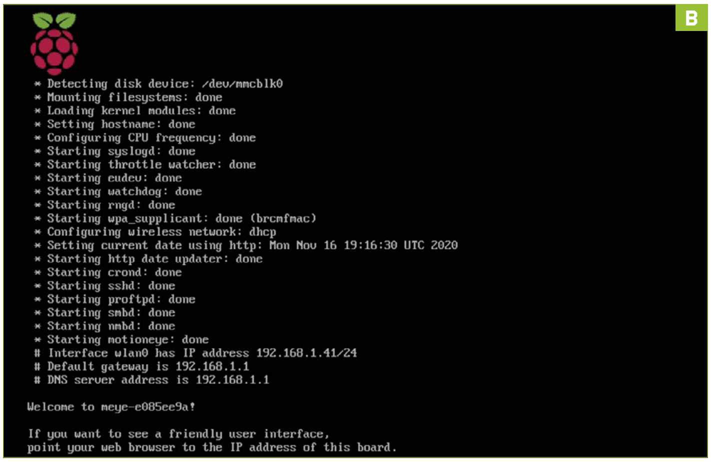
4. CAMERA SETTINGS
The most important menu. Change the camera's resolution and frame rate here, and flip the video over if the camera's been installed upside down.

5. OTHER SETTINGS
There are so many, we could be here all week. The key to a successful installation is correct configuration with reference to the online help files.

6. CAMERA FEEDS
Camera names and dates are superimposed over the feeds. You can add extra buttons too, in order to execute custom commands.

2 FIRST BOOT

You'll know that it's working once a green light flashes on the board, and a red raspberry graphic appears on the screen, along with some text. You won't need the screen for most of this, but it's handy to have at the beginning. It takes a while to boot the first time, while it sets up its hardware, but eventually you'll be faced with a login prompt and a welcome message telling you to go to the board's IP address for a more friendly interface [**Image B**]. The IP address is listed above this: Type the address itself—anything after it (such as /24) generally gets you an error message.


B

```
 * Detecting disk device: /dev/mmcblk0
 * Mounting filesystems: done
 * Loading kernel modules: done
 * Setting hostname: done
 * Configuring CPU frequency: done
 * Starting syslogd: done
 * Starting throttle watcher: done
 * Starting eudev: done
 * Starting watchdog: done
 * Starting rngd: done
 * Starting wpa_supplicant: done (brcmfmac)
 * Configuring wireless network: dhcp
 * Setting current date using http: Mon Nov 16 19:16:30 UTC 2020
 * Starting http date updater: done
 * Starting crond: done
 * Starting sshd: done
 * Starting proftpd: done
 * Starting smbd: done
 * Starting nmbd: done
 * Starting motioneye: done
 # Interface wlan0 has IP address 192.168.1.41/24
 # Default gateway is 192.168.1.1
 # DNS server address is 192.168.1.1

Welcome to meye-e085ee9a!

If you want to see a friendly user interface,
point your web browser to the IP address of this board.
```

© MOTIONEYEOS

3 WEB INTERFACE

Go to the web interface on another computer, cellphone, or tablet. The web interface is much nicer than the text-based output from the Pi itself. If you're asked to login, the default admin account is "admin" with no password (there are two users, admin and user, with the latter meant for everyday use). If you're going to deploy motionEyeOS as a camera system, you'll want to add some passwords, but for now it will do. At the left-hand side of the interface is a three-line menu button, and the first place you should go is "Software Update" under General Settings—if there's an updated version of the OS available, it'll download and install without much input from you. You can shut down and restart the board from the same place. Your initial camera will be in a window near the center of the interface, and by selecting the camera in the settings menu you can tweak settings, such as frame rate or resolution.

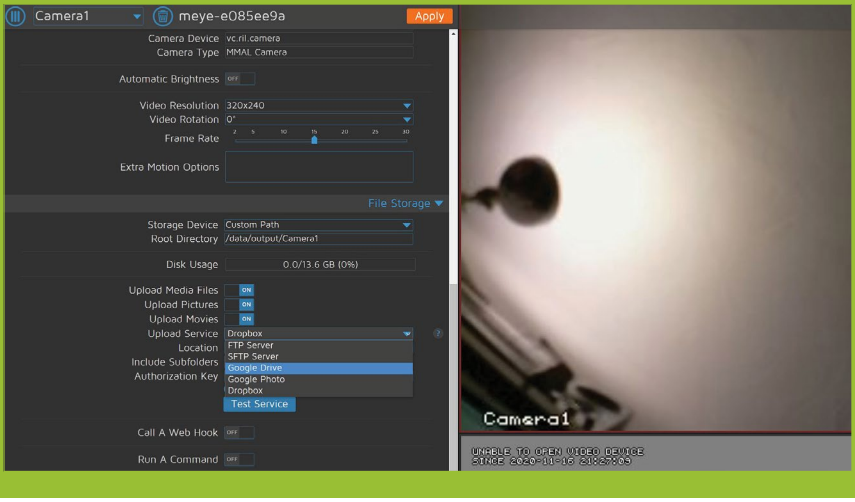
Join the conversation!

Discuss all things PC gaming with fellow readers at our official forums

forums.pcgamer.com

PC GAMER

THE CLOUD



Camera Device vc.ril.camera
Camera Type MMAL Camera
Automatic Brightness OFF
Video Resolution 320x240
Video Rotation 0°
Frame Rate 2 5 10 15 20 25 30
Extra Motion Options
Storage Device Custom Path
Root Directory /data/output/Camera1
Disk Usage 0.0/13.6 GB (0%)
Upload Media Files ON
Upload Pictures ON
Upload Movies ON
Upload Service Dropbox
Location
Include Subfolders
Authorization Key
FTP Server
SFTP Server
Google Drive
Google Photo
Dropbox
Call A Web Hook OFF
Run A Command OFF

Of course, you can upload stills and videos to the cloud. Alongside options to save them to the FTP and Samba shares on the board's microSD card, there are entries on the dropdown menu under "File Storage for Google Drive, Google Photos, and Dropbox." This opens it up for use with IFTT, perhaps triggering a phone alert when a new image is uploaded to the Google Drive folder, or extending the built-in email system. This is also a useful security measure, as a burglar who discovers your system may try to swipe the microSD cards to cover their tracks —they can't do the same to Google Drive.

4 ADD A NEW CAMERA

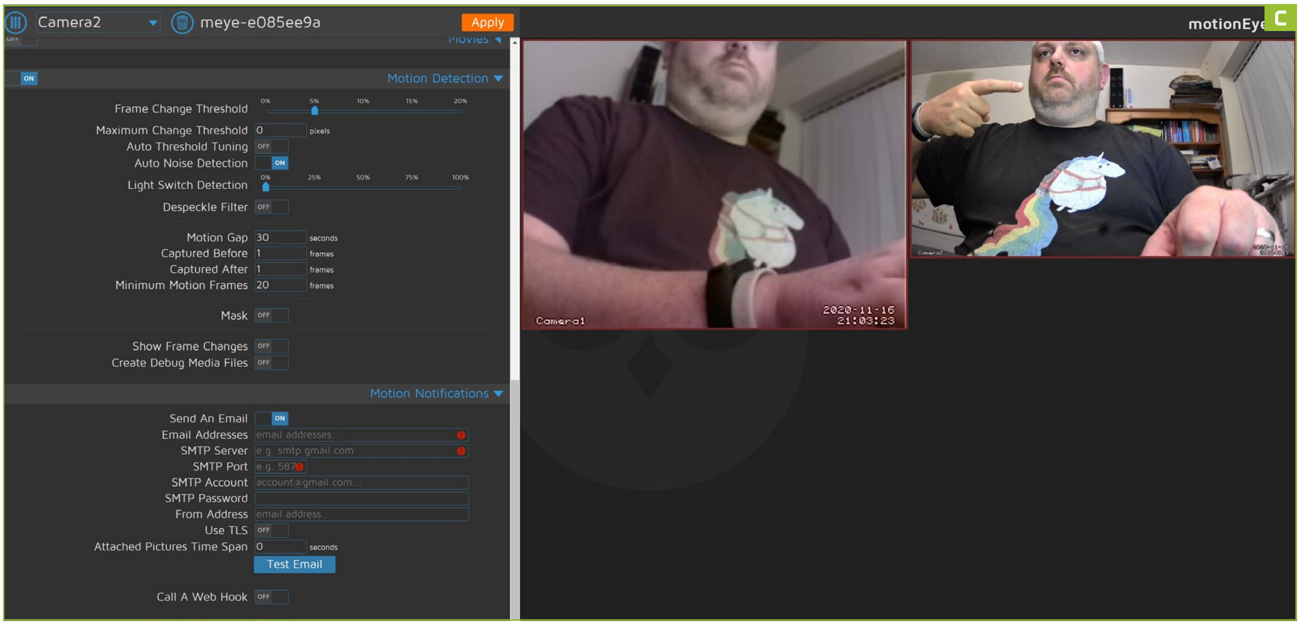
You're not limited to one camera in motionEyeOS. Although there's only one dedicated camera port on the Pi Zero board, it does have a USB socket through which we can add another. Pulling the USB webcam off the back of our gaming PC, we plugged it in with a USB OTG adapter, and hit "Add Camera" in the camera dropdown menu at the top right. The USB webcam is a different type to the one on the camera port, but with a bit of trial and error we found a setting that worked. The more cameras you add, the greater the strain on the board, and our Pi Zero was easily overwhelmed.

5 MOTION DETECTION AND RECORDING

"Motion" is aptly named for its motion-detecting abilities. You access these from further down the menu, and can set how much of the frame has to change to qualify as motion—perhaps to stop a gentle breeze from triggering an alert—as well as what happens when it's detected. Possibly the most useful is to receive an email [**Image C**], and the OS runs both FTP and Samba servers for you to access the still images and videos it can record of motion events. This uses local storage on the Pi's microSD, and although the OS itself is tiny, video files can take up much more space, so consider your needs if setting up a surveillance network, and buy cards of suitable speed and capacity.

6 LIMITATIONS

In hindsight, the Pi Zero wasn't the right board for this. It worked, but with frame rates in the region of one every five seconds, it's not the ideal way of setting up a multi-camera system or detecting motion. Even reducing the cameras to their lowest resolution and enabling some overclocking features on the Pi didn't help. However, we can imagine that outfitting a Zero with one camera (a model with both day and night-vision capabilities), and having it feed to a Pi 4B configured as a hub for several Zeros, and streaming to a second Pi with a monitor, might work very nicely. ⏻



C

ON
Frame Change Threshold 0% 5% 10% 15% 20%
Maximum Change Threshold 0 pixels
Auto Threshold Tuning OFF
Auto Noise Detection ON
Light Switch Detection 0% 25% 50% 75% 100%
Despeckle Filter OFF
Motion Gap 30 seconds
Captured Before 1 frames
Captured After 1 frames
Minimum Motion Frames 20 frames
Mask OFF
Show Frame Changes OFF
Create Debug Media Files OFF
Send An Email ON
Email Addresses email addresses...
SMTP Server e.g. smtp.gmail.com
SMTP Port e.g. 587
SMTP Account account@gmail.com...
SMTP Password
From Address email address...
Use TLS OFF
Attached Pictures Time Span 0 seconds
Call A Web Hook OFF

Machine of the Month: Apple II (1977)

YOU'LL NEED THIS

APPLEWIN
We couldn't find any minimum requirements for AppleWin, but not much. Really not much. A solid version of Wine if you're using Linux.
https://github.com/AppleWin/AppleWin

THIS MONTH WE EXPLORE the brainchild of Apple's other Steve, the genius that is Steve Wozniak. The Apple II (stylized as the Apple][) was one of the original mass-market home computers, but would become synonymous with color computing, distinguishing itself from rivals made by Commodore and Tandy. Unhappy with the state of personal computing, Wozniak wanted to create something "small, reliable, convenient to use, and inexpensive." Following the stylistically crude but technologically promising Apple 1, Wozniak wanted to create a machine that was faster and more practical, with color graphics.

While Steve Jobs concerned himself with selling the machine and making it pretty, Wozniak would create a piece of engineering beauty still admired today. Widely regarded as a primary influence on the IBM PC, the Apple II created the first real platform with long-term support for home consumers, with an emphasis on open architecture and expandability. With an astonishing production run stretching from the '70s to the '90s, the Apple II would be the machine to launch the company into the mainstream, and be its main source of income for over a decade. **–JOHN KNIGHT**

1 SIMPLE SUBSTANCE

Elegant simplicity is the central theme behind the Apple II and Wozniak's engineering methods: He had an obsession with using fewer components, stripping things back to their most elegant form, adding reliability and lowering prices. In multiple areas, Wozniak found clever workarounds that removed the need for extra RAM and chipsets used by the competition, while adding color graphics.

» Launching in June 1977, the Apple II was based around the trusty MOS 6502 CPU and shipped with 4KB of RAM, but wealthier owners could easily expand to 48KB in minutes. Initially the II used cassettes for storage, but it wasn't long before users demanded floppy support. Wozniak's resulting floppy drive is particularly famous among engineers, being stripped back and redesigned to the point where it cost a fraction of existing units.

» If you're a die-hard PC fan who rages at the very mention of Apple, don't worry, it's OK to like the Apple II! Being primarily a creation of Steve Wozniak instead of Steve Jobs, the Apple II is a fundamentally different product to the Apple of today, following almost opposite ideals.

» Based around open architecture, the Apple II is generally regarded as a primary influence on the IBM PC, and would even spawn numerous clones, such as the Franklin ACE 100 and VTech's Laser 128. Something to embarrass most PCs: The Apple came with eight expansion slots, and even had an easy-access lid.

2 THE BEGINNINGS OF APPLE'S SUCCESS

The Apple II found its foothold in the business world with the release of Software Arts' VisiCalc (1979), the first proper spreadsheet for home computers. Demand for the machine soon spread beyond American borders, forcing engineering modifications for Europe and Japan (French software titles are particularly common). The Apple's color graphics and simple operation also made it a hit among gamers—any classic eight-bit title is likely to have an Apple II port.

» Despite Apple betting that the Apple II would only last a few years, strong sales continued for far longer than anticipated, backing up the company while products such as the Apple III and Lisa failed.

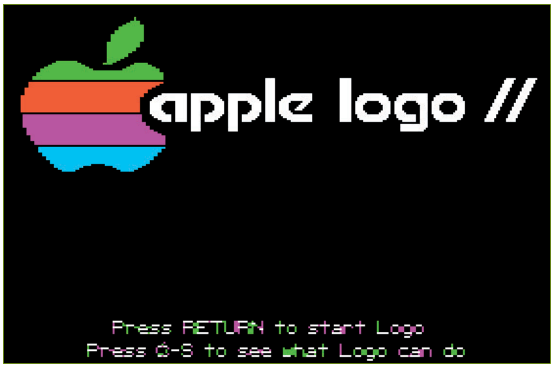
» Re-focusing attention on the II, Apple used newer technology to update the line with models such as the hugely popular Apple IIe (1983), which slashed costs by stripping the number of components to less than a third, while adding RAM. Apple would shrink the II further with the IIc (c meaning "compact"), launching in 1984 and lasting until 1990.

» The Apple II name would continue into the '90s with the IIGS line, but this was really a whole new computer, with a 16-bit CPU and full-color desktop—something we'll save for a future issue. The Apple II finally earned its true retirement with the Platinum IIe, which was discontinued in November 1993, almost a year after the 16-bit IIGS.

» It had sold over 5 million units (6 million including the IIGS) over three separate decades.

3 EMULATING THE APPLE II

There are plenty of emulators available, including general-purpose and even browser-based options, but we prefer something bespoke. Our choice is AppleWin—it has the friendliest interface by far and excellent emulation. AppleWin is currently Windows



Press RETURN to start Logo
Press -S to see what Logo can do

» **The II also launched Apple's familiar rainbow-striped logo, highlighting the machine's color graphics.**

© ALIENS, ACTIVISION, 1986

» **Steve Jobs actually "did" involve himself with the IIc. Unsurprisingly, it's prettier and less functional.**

© MARK MADEO [FUTURE PUBLISHING/HE COMPUTER HISTORY MUSEUM]

only, but if you're a Linux user, AppleWin is GPL open source and runs excellently under Wine.

» If you would prefer to use native Linux software, Apple II cores are easily available for general-purpose emulators like MAME and RetroPie. But for Apple II-specific emulation, we can also recommend The Octalyzer, microM8, and LinApple (though LinApple needs to be compiled from source). Our chief pick would be microM8, which has an interesting keyboard-driven interface: https://paleotronic.com/software/microm8/

» Returning to AppleWin, the provided link takes you to a Github repository. Towards the bottom of the page is a link labeled "Download latest (stable) release." Grab this, and once downloaded, extract the zip file and open the new folder. AppleWin doesn't come with an installer, so you'll need to open the Applewin.exe executable manually—you might want to make a desktop shortcut.

4 USAGE

By default, AppleWin emulates the Enhanced Apple IIe, which had an auto-boot facility. That will make it very easy to get started. Just click the floppy drive icon labeled with a "1," choose the program you want to load into the virtual floppy drive, then click the colored Apple icon to start/restart the machine.

FINDING SOFTWARE

If you're after trying out some free software then https://archive.org has plenty of programs for you to get stuck into and play with, including both games and work applications.

If you can't be bothered to install an emulator, Virtual Apple][runs in your browser and has a great collection of software for both the II and IIGS. It even has extra controls allowing you to switch between color and black and green single-color mode. The browser plugin only works under Windows and Mac, so definite points off there, but at least it provides disk images that an emulator can use: http://virtualapple.org

However, the most interesting resource is Call-A.P.P.L.E., which has been serving the Apple community since 1978. Here you can find everything from books and magazines to new games made by fans. There we found links to the work of Vince Weaver, who has been making blocky eight-bit reworks of *Myst* and *Another World*—a fabulous waste of time that gets our official thumbs up! https://www.callapple.org/

» If you have a program spread over multiple disks, you can use the second virtual floppy drive as well. The icon below enables you to switch the drive order, in case you need to do any mid-program disk swapping.

» Once a program is launched, "Alt + Enter" will enable full-screen mode. Assuming you don't have a real joystick connected, AppleWin will emulate a joystick via the keyboard. By default this will use the number pad for movement, and the "Alt" button for fire, but this can be changed in AppleWin's configuration window.

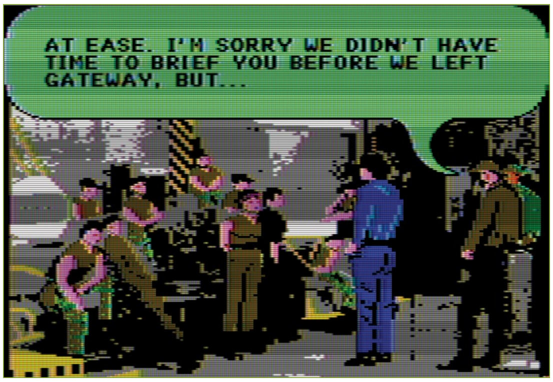
» To configure AppleWin, click the icon with the picture of a speaker and a joystick. Of primary interest in the "Configuration" tab are "Model" and "Video." "Model" will be set to Enhanced Apple IIe by default, but can be set to older models like the original Apple II, or a "Clone" machine. "Video" will be set to "Color TV" by default, but if you've never seen Apple II color graphics before, you may find it unattractive! Other options are available, such as a proper monitor, or monochrome.

» In the "Input" tab, you can define your joystick inputs, including whether to enable a joystick or not, whether to use keyboard emulation with the number pad or cursor keys, with a mouse, or select an actual joystick. ⏻

SPECIFICATIONS

Apple II (1977)

CPU:	MOS Technology 6502 @ 1.02 MHz
RAM:	4KB up to 48KB
Launch price:	$1,298
Graphics:	16 colors @ 40x48, 6 colors @ 280x192
Sound:	CPU-driven 1-bit speaker
Storage:	5.25" floppy, audio cassette, later hard disk upgrades
OS:	Integer BASIC/Apple DOS
Released:	June 1977
Production:	1977-1993
Worldwide sales:	N/A


AT EASE. I'M SORRY WE DIDN'T HAVE TIME TO BRIEF YOU BEFORE WE LEFT GATEWAY, BUT...

» **Woz used clever engineering tricks to achieve color, though it can have a strange washed-out look at times.**

BUILD IT

ZAK STOREY, EDITOR

Super Storage Station

Building our own full-tower storage house

LENGTH OF TIME: **1-2 HOURS**

LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

OH BOY this is a big one. It's one of those builds that you sort of plan out at first, thinking, "Ah this will be easy, and affordable, and realistic," and then you get to the end of requesting in all those parts and what you're left with is a massive price tag. It happens more often than you'd think. Yep, if you take a quick glance over to that ingredients list to the right, you'll see that our secondary storage of choice takes up a whopping 67 percent of our total budget. That's nuts.

However, it does bring to light one perhaps obvious fatal flaw when it comes to a system build quite like this. As you can probably tell the concept behind this build is simple: To create a fantastically concrete media server, where we can store our future *Maximum PC* video content (planning for the new year, for when the HQ opens up and we get access to that dreaded digital format as part of this editor's grand plans). But there's one problem for the average Joe—that it is an insane amount of money to spend on storage.

The reality is, if you swap those out for just standard Western Digital Red Pro 4TB HDDs, you'd be looking at a price of around $600. That's near enough a third of what you'd actually spend on those SSDs—crazy huh? SSDs have come a long way for sure, and their performance is undeniably superior in almost every metric, but they're just nowhere near the same cost-effectiveness when it comes to mass storage and server setups like this.

PERFECT STORAGE?

SO REALISTICALLY, unless you need super-fast storage, dropping $1,740 on SSDs might not be the smartest idea. In fact, there's a few areas with this build where you can swap parts around, and interchange stuff to really tailor it to your specific requirements. For instance, if you want to make this a media-streaming build for your whole family, you might be better off getting a 24-core Threadripper, and a dedicated GPU with some solid 7,200 RPM HDDs. If you are looking to create a remote rendering station, then dropping storage capacity by half and investing in a lot more memory would go a long way. Want an ultimate gaming rig with a boat load of storage in the back? Then a Ryzen 9 5900X, AMD Radeon RX 6800 XT, and 4TB of SSDs would be a perfect solution.

There's a ton of ways you can customize this very specifically to your needs. The reason we've gone the way we have (aside from the aforementioned need for somewhere to back up our video content) is first and foremost because we really want to see just how good Phanteks's Enthoo Pro 2 is when it comes to building a NAS-like media server.

And the thing is a beast. Complete with ample airflow, support for two systems, oodles of GPUs, and even twin-socket motherboards if you so desire, this thing is a monster. In fact it's so big you could theoretically fit 12x 3.5-inch drives and 3x 2.5-inch drives all at the same time. As standard there's support for 4x 3.5-inch drives and 11x 2.5-inch SSDs with brackets included. As an aside, to get that extra storage space, you'd have to buy an additional four pairs of brackets from Amazon, at $14 a go, bumping up the total case price to $196 (search PH-HDDKT_03). Not too shabby. But enough of that, let's get to it.

INGREDIENTS

PART		STREET PRICE
Case	Phanteks Enthoo Pro 2	$140
Motherboard	MSI MPG Z490 Gaming Carbon WiFi	$264
CPU	Intel Core i5-10500	$240
Memory	8GB (2x4GB) Corsair Vengeance LPX @ 3000 CL16	$41
PSU	500W EVGA BR 80+ Bronze	$65
Primary Storage	20GB Western Digital Green M.2-2280 SSD	$38
Secondary Storage	12TB (3x4TB) Western Digital Red SA500 2.5-inch SSDs	$1,740
CPU Cooler	Noctua NH-U12S	$60
OS	Windows 10 Home 64-bit OEM	$25
Total		$2,613

1

GUTTING MONSTERS

THERE'S NO DOUBT about it: The Enthoo Pro 2 is big, seriously big. It comes in at 9.5 x 22.8 x 22.0in (WxHxD) and weighs 28.7lbs empty. That's huge. It's got space internally for multiple systems, dual-socket mobos, and up to 1,820mm of liquid-cooling radiator surface area if you so desire. It's just so versatile, it's extreme.

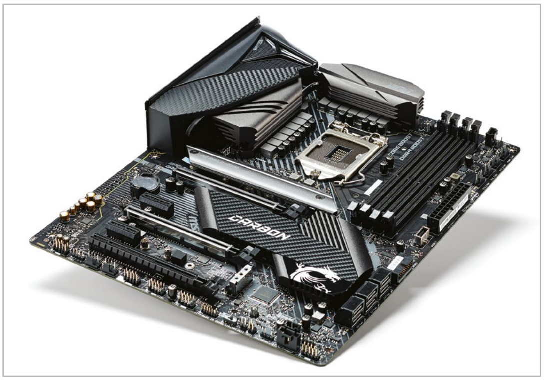
To get this far, pop the front panel off by pulling from the bottom, remove the magnetic dust filter on the top, and carefully place the tempered-glass side panel and rear panel into the cardboard box it came in. Sticking them between the packing material ensures that you don't lose them, and that nothing scratches them throughout the build process.

2

MOTHERBOARD BRIGANDS

OUR MOBO is MSI's Z490 Gaming Carbon WiFi. It's not a mind-blowingly expensive board, but packs in enough features to keep us happy, suitable for our Core i5-10500, up to 128GB of DDR4, and six SATA connections straight out of the gate. It's the I/O that interests us the most, as it comes with a 2.5G Ethernet connection, multiple USB 3.2 Type C ports, and WiFi AX 6 as well, meaning as far as getting data to this machine goes, we've got options.

It's even got a PS/2 port if we want to get old school. There is one slight problem: If we want to add drives to our array at a later date in the form of 3.5-inch HDDs we're going to have to install an add-in RAID card as well. Six SATA ports just ain't going to cut it.

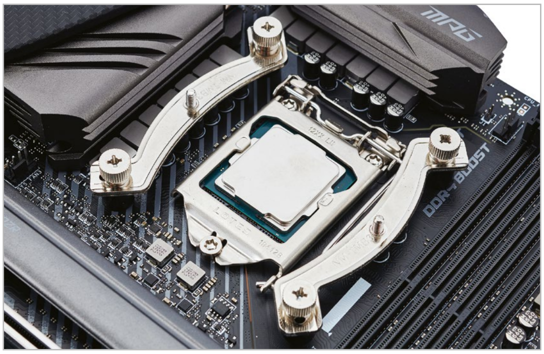


3

CPU PREP

IT'S NEVER A BAD IDEA to go over how to install an Intel processor. Out of the two socket types, LGA is by far the most terrifying, and installing either Intel chips like this, or AMD's gargantuan Threadrippers, into a pinned socket like the one here is still nerve-wracking. So lift up the retention arm, raise the bracket and the cover, carefully place the processor in, aligning it with the notches on the socket and the triangle etching. Place the bracket and cover down under the screw at the bottom, secure the retention arm, the plastic cover will pop off, and breathe.

We'll also install our mounting socket for the Noctua NH-U12S. Place the backplate on, pop the spacers on top, put the metal mounting brackets in the correct orientation, then secure down with the thumb screws.

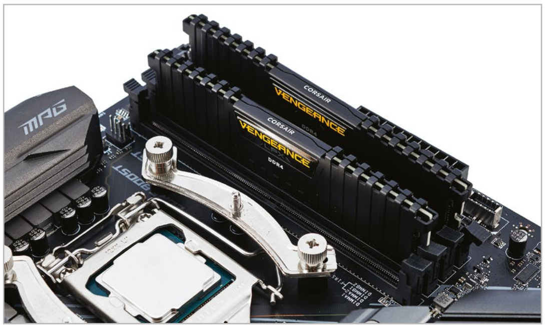


4

MINIMAL MEMORY

WE'VE GONE FOR LESS MEMORY than we usually do, but this machine's going to be on pretty much every day from 9 till 5, and only running a basic OS, with a backup schedule and a few other monitoring programs on it. To that end, we've gone with two sticks of Corsair's Vengeance LPX memory at 3000 MT/s, for a grand total of 8GB. For our Core i5-10500 and storage ambitions this should be plenty, to maximize our efficiency and (laughable) cost-effectiveness. If we swap to a Threadripper chip later on, we'll swap these out for 64 or 128GB of high-spec DDR4.

To install, lift up the tabs at both ends of the DDR4 slot, and align the memory stick with the notch in the center and the notch on the slot itself. Always install your memory in the correct channels, but it's usually every other slot for a single pair in a four-slot board.

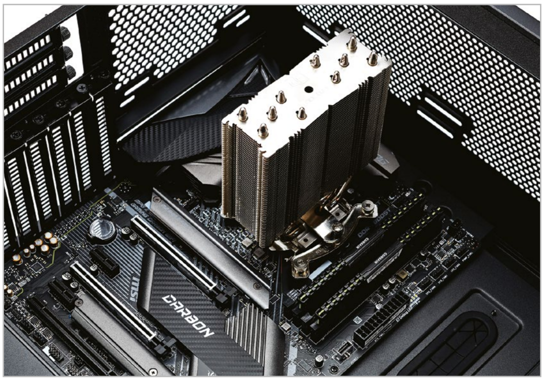


7

FLAME ON!

IT'S TIME TO get that processor ready. Apply some thermal paste to the processor (a little splodge in the middle of the chip will do; make sure it's a non-conductive paste), and position the tower over the two mounting screws in the middle of the Noctua mounting bracket. Using a screwdriver, push down and tighten each screw a bit at a time, going back and forth between the screws, so you don't place undue stress on the processor. Always do this by hand, and refrain from using a power tool.

After that, install the fan into the correct position, attach the two included fan brackets to the Noctua fan, and place it on the cooler, so it's pushing air through the tower and out the rear. Plug that into the CPU fan header.



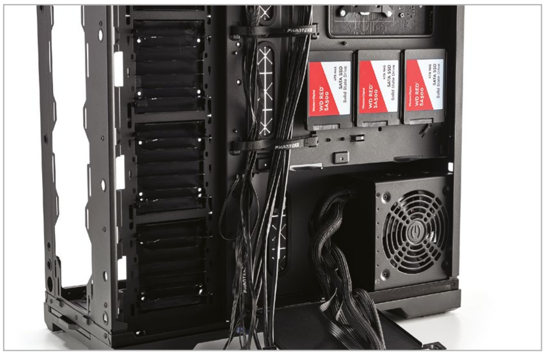
8

INSTALLING THE LOT

LET'S GET BUSY installing the key component of this build, those ridiculously expensive SSDs. We're going to be running these without redundancy, as the drives will technically be the redundancy for additional storage found within our personal work machines—at least until we reach the point where our storage gets too large, and we have to expand with more SSDs, or swap to HDDs.

Remove the brackets on the back of the mobo tray (these slide up and out), then install the drives with the Phillips screws underneath. Slot them back into position, making sure the connection points are facing down.

It's also time to get the power supply in. Use the included screws to secure it vertically. There's ventilation in the rear panel, so it's not going to choke and overheat!

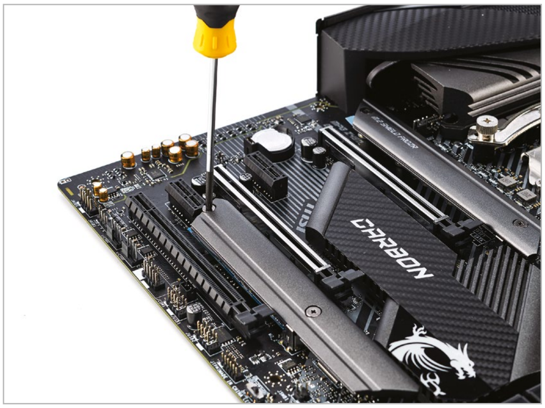


5

GREEN FINGERED

IT'S TIME TO INSTALL our M.2 OS drive. To do this, locate the M.2 heatsink at the bottom of the board, and remove the two Phillips-head screws from the plate. Lift the heatsink off, and identify the correct M.2 slot. Place the M.2 drive in the M.2 slot, making sure to note the orientation of the notch in the slot and the drive itself (this is to ensure that the NAND and controller chip are making contact with the heatsink), then pop the heatsink back down and secure with the same screws.

Make sure you also remove the "laird" thermal pad plastic cover, before securing the heatsink back down, to maximize thermal efficiency.

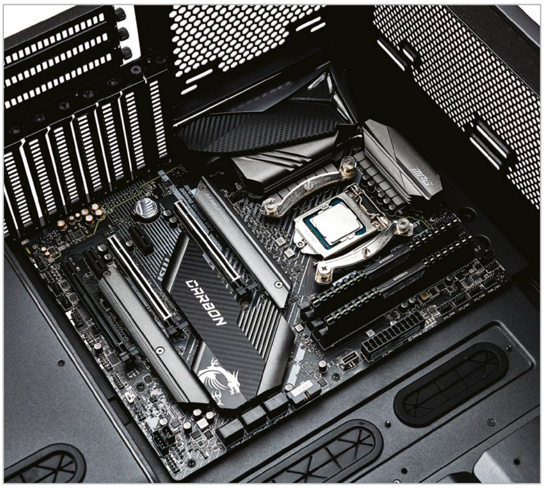


6

ALL ABOARD

NOW THAT THE MOTHERBOARD has been successfully prepared, it's time to get it inside the chassis. To do this, line up the motherboard with the mobo stand-offs internally, and carefully place it down, making sure that the integrated rear I/O plate is correctly aligned with the cutout at the back of the case.

Once it's in, secure the mobo in place, securing each corner first, with the correct screws found in Phanteks's jazzy accessory box (that came with the case).

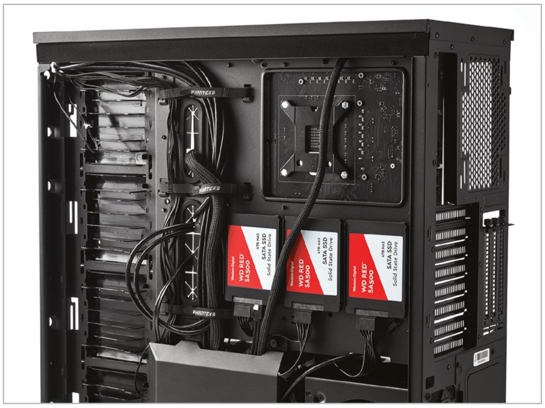


9

CABLE CHAOS

WITH THE DRIVES IN PLACE, it's time to plug in all those cables. You'll need the 24-pin for the motherboard, an eight-pin for the CPU socket, and a daisy-chained SATA power for our three drives spotted here. You'll also need to grab three of the SATA cables found in the motherboard box, to plug the drives directly into the board itself.

On the whole cable management in the Enthoo Pro 2 is a pretty seamless affair with little trouble. Phanteks has even included this cable cover next to the PSU to hide any unwanted mess, although it's a bit less effective, especially given all the I/O cables running up the top channel in the middle there, but the Velcro ties help keep them in place.

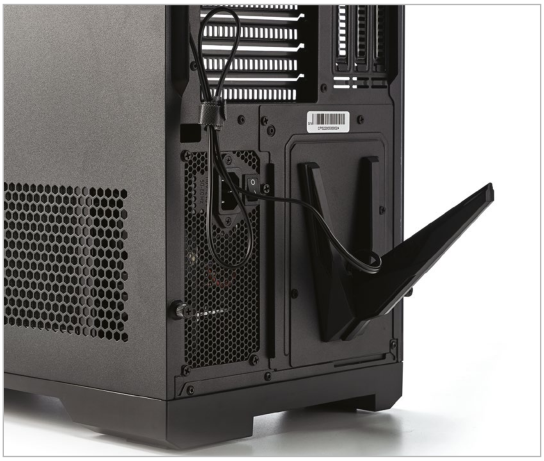


10

WIRELESS ASCENDANCY

LAST BUT NOT LEAST, we've decided to install our cute little magnetic Wi-Fi antenna to the back of the case. We've used one of the included Phanteks Velcro straps to tie it together, and run it up the back of the case to the ports on the motherboard itself. It's nice, simple, and looks surprisingly good.

And there you have it: One completed, ridiculously overkill NAS backup server, ready for the future plans of *Maximum PC* in 2021 and beyond. And boy does it look empty, but more on that in a moment.



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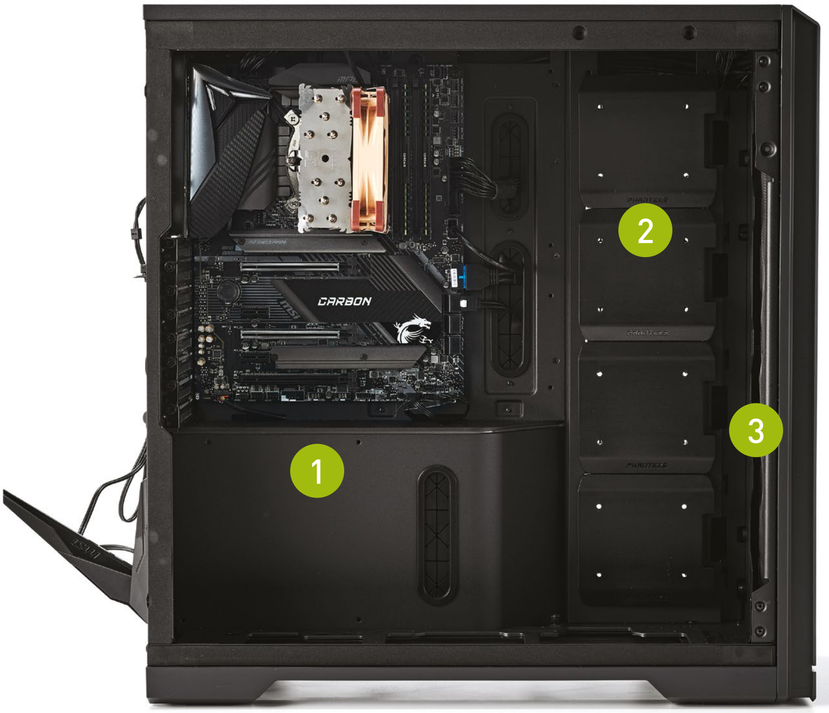


1 There's some serious space in this build. Theoretically if you wanted you could place an ITX system here below the motherboard, to handle all of your Twitch streaming escapades.

2 Each of these plastic covers on the right of the chassis can have an SSD installed, or be replaced to allow for more HDDs.

3 We've not really taken advantage of the cooling in this chassis just yet, as our build's going to be stationary in an air-conditioned office, but the front provides plenty of intake if we do need it.

THE END?

THIS HAS BEEN a fairly simple build to put together. There haven't been any major hurdles to overcome. The biggest problem was stretching those budget ATX power supply cables up and all over the place. That budget EVGA PSU is a fine bit of kit if you're not pulling much juice from the wall, but in a case of this caliber, it does leave something to be desired when it comes to cable length.

What might be a solid upgrade path in the future (especially if this turns into a rendering station) is to install a 750W or greater Corsair RMx PSU, with a set of its pro cables as well. These things are monstrously long (so long we were forced to use them in our Dream Machine 2019 build) that they'd be an ideal candidate for the gargantuan size of this thing.

Cooling is also something that could do with an upgrade. As standard we don't have any fans drawing air into this build at all, and we could really use some intakes at the front, especially if we opt for something a bit more substantial on the processor front. For the time being, our armada of SSDs and single six-core chip won't exactly demand that much access to cool air, but if our grand schemes come to fruition it may be something we need to reconfigure later on down the line.

Outside of those minor component niggles, there's not a whole lot to report on here. The build was a fairly seamless process, as always with Phanteks chassis, cable management was a breeze, and the general build process and procedure was simple and easy to do. Nothing really got in the way, or had to be installed via some gratuitously complex masonic handshake. It all came together quite nicely. Heck, even that tinge of RGB running along the plinth isn't too gross (although we won't be configuring that in software anytime soon).

As for performance, well it's very predictable. We managed to get up at 532 MB/s on sequential read and 512 MB/s on the writes, Cinebench R15 scored 1,175 points in its multi-threaded test, and temps remained fairly concrete at just above 82C under full load in Prime95. This isn't a machine designed for gaming at all, and testing in that segment seemed a bit futile, so we opted for some additional random 4K tests instead.

As for power-draw under load, we saw a max pull of 187W after five minutes under Prime95, but the reality is this system will rarely ever hit that mark in its day-to-day life, so we're not worried. That does mean the 80+ Bronze PSU is woefully inefficient, but if we do even minor incremental hardware updates it should give us enough leeway to add extra drives, or even a low-powered GPU if the need arises.

Ultimately, this build is a pretty solid media server, and will serve its purpose well as our primary video content backup going forward, and although it's obscenely expensive, we're happy with the result. ⏻

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,421	1,175 (-17%)
CrystalDisk QD32 Sequential Read (MB/s)	3,534	532 (-84%)
CrystalDisk QD32 Sequential Write (MB/s)	3,170	512 (-84%)
CrystalDisk QD1 Random 4K Read (MB/s)	58.54	37.42 (-36%)
CrystalDisk QD1 Random 4K Write (MB/s)	143	94.38 (-34%)
CPU Temp Under Load - Prime95 (C)	61	82 (-34%)
System Power Draw Under Load - Prime95 (W)	472	187 (60%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i5-10600K, 16GB of DDR4 @ 3600, a Zotac GeForce RTX 2080 Super AMP Extreme, and a 2TB Samsung 970 Evo Plus M.2 PCIe 3.0 SSD.

LAB NOTES

TESTED. REVIEWED. VERDICTIZED.

Historical Accuracy

My frustrations with Assassin's Creed: Valhalla

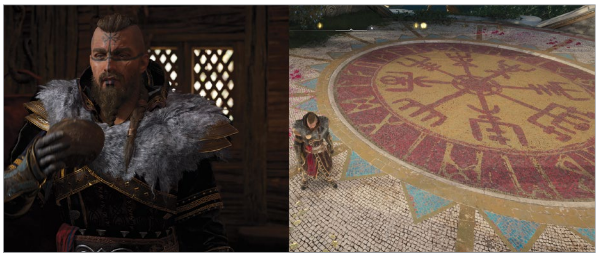
LOOK, I get it, historical accuracy and video games isn't really a thing. So when *Assassin's Creed: Valhalla* was first announced, I knew, given my obsession with Nordic culture I was going to be playing a lot of it, most likely frustrated.

Now, there are two major symbols repeated throughout the game, the most common being the Ægishjálmur, and the other being the Vegvísir. The Ægishjálmur in particular is meant to be eight Algiz runes bound in a circle. The Algiz rune symbolizes protection (apparently). Yet the Ægis symbol is nothing to do with the Viking era at all. In fact the name itself originates from a passage in *The Saga of the Volsungs*, which as far as we can tell originated around the 13th century CE (200 years after), and documents Sigurd's slaying of the dwarf-turned-dragon Fafnir among other tales (a brilliant read).

The Ægishjálmur symbol originates from the 16th-18th century in Iceland. And as far as any historical source worth its weight is concerned, was actually used in the practice of "dark magic", rather than this symbol of protection that modern romantics have given it. The same goes for the Vegvísir. In fact both these symbols have more in common with Abrahamic religions than any form of Viking paganism or cultural beliefs.

Now in the modern romanticization of this culture, we see these symbols rather a lot, alongside the Elder Futhark runes as well (a more dramatic runic language not actually used in the Viking era either). It's frustrating because as far as archeological and historical knowledge goes there's over 1,000 years between these two things actually existing.

I'm still enjoying the game, and we will have a full review of it for you next issue, but come on Ubisoft, get your runes right. You certainly hired enough historians to put this thing together, so at least give the culture the respect it deserves.



It's a very good, pretty game, but fraught with runic inaccuracies.

INDUSTRY INSIDER

Oh I so want to upgrade my rig. With Ryzen's 5th (4th?) generation of processors finally landing with us, and Zen 3 becoming the juggernaut it was always destined to be, the temptation to move across to Team Red is undeniable. Couple that with the intriguing promises tantalizingly teased with Radeon's RX 6000 series interacting even better with Ryzen processors thanks to their shared lineage, and it's a tempting opportunity to swap from Intel and Nvidia.

My only worry here? Driver updates and dealing with AMD Catalyst Center, or whatever it's being called this month. It's a big worry for me. Typically AMD's drivers have always been a bit slow to the party compared to Nvidia's, and it's a genuine concern. After all, it's had considerably less market share over the last four years, and so, far less money will have been pumped into the R&D side of things, including driver development.

The last time I used Catalyst Control Center on my daily rig, it was a nightmare—all right, so that might have been with the Fury X many years ago (anyone else miss consumer-facing HBM memory?), but still, it really worries me. Am I just being unreasonable though? Times have changed, AMD has wowed me once with Ryzen when it first launched, can it do it again with Radeon? Let's hope so.

© GETTY IMAGES

Editors' Picks: Corsair Katar Pro Wireless Mouse

Corsair's plucky little wireless mouse packs in lightning-fast connectivity across Bluetooth and 2.4 GHz Wi-Fi

I AM still ever fighting my darn MacBook, trying to find the ultimate mouse to satisfy my clicky needs: Seriously if anyone's used a 3D touch trackpad on one of these things, you'll know, if you're a regular Windows user at the very least, it's about as intuitive as getting hit in the face with a spring-loaded soggy fish attached to a piece of 2x4. It's just not easy to right click, or to select things and drag them, or scroll. Honestly it's just grossly over-engineered nonsense, to try and be edgy and secure a few more sales for one of the world's wealthiest companies as far as I'm concerned, and I for one don't care for it. I know it has fans out there, and I'm sure there's some applications where it's useful, but for me, and the software I use on that MacBook, it's just "not good", which is definitely the two words I would use, and not some other form of crude expletive.

So since lockdown, and being bound to this pesky MacBook for all of my mag management, I've been leaning heavily on Logitech's G603 wireless gaming mouse. It's a fairly good choice. It's got a good battery life, a relatively comfortable, ergonomic feel, and the sensor works well. But over time, I've sort of fallen out of love with it for two reasons. One of them is software-based: When the mouse goes into sleep mode, the MacBook refuses to identify it again, and I have to un-pair it and re-pair it again every time, (this is likely related to the corporate image deployed on my MacBook more than anything). My other issue is the feel of the thing. It's just too big, and the material itself feels a bit cheap. So this issue Corsair sent me the Katar Pro Wireless.

So what are the specs? Well it's 96g (compared to the G603s 136g), comes with a single AA battery, has a far smaller frame, feels a touch nicer, and features a similarly potent sensor capable of up to 10,000 CPI. It also has the same number of programmable buttons, a flicker of lighting, and some of that new Corsair styling I'm so fond of. Downsides in comparison to the G603 include the battery life—which sits at 135 hours of continual use in high-performance mode, compared to the 500 hours in the G603—and its sensor, which isn't quite as impressive (but this is being used on a work Macbook, not a gaming PC, so I'm not too bothered).

The big advantage the Katar Pro Wireless has, however, is the price. It's about $20 cheaper than the Logitech G603 (at the time of writing Amazon has it on sale at $25, a further $15 off), and that's a fairly big deal if you're looking for a quality, affordable wireless/Bluetooth mouse.

In day-to-day use the Katar Pro does seem to connect better, and I see far less connectivity drops (but again that could be down to Future's weird corporate Mac image), and on the whole it's accurate, precise, and works exactly how I want it to in this environment. It's a bit on the smaller side, so ideal for travelling, but for long gaming sessions where ergonomic comfort is key, I'd likely still opt for something with a bit more clout, or fall back on my daily driver (the Mionix Castor). But all in all it's a solid pick; there's not a lot here I'd complain about. It's a bit frustrating that it actually functions off an AA battery instead of an integrated one, but that does increase its run time quite considerably, and once you swap it out with a rechargeable battery, well it's less of an issue really. **–ZS**

$40, www.corsair.com

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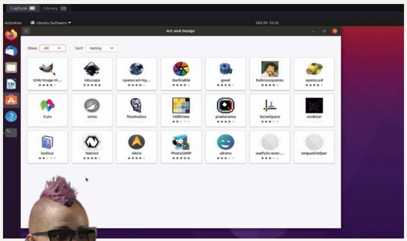

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AMD Ryzen 9 5900X
AMD
RYZEN

12 cores and 24 threads of Zen 3 heaven.

AMD Ryzen 9 5900X

The underdog takes the lead

LET'S CUT TO THE CHASE: The performance of the Ryzen 9 5900X and AMD's latest Zen 3 architecture is good. It's really good. It pretty much delivers on the promise that AMD laid out at the chip reveal on October 8, and if nothing else that should make for very worrying reading for Intel. For us gamers that is nothing but good news, because there is now real choice when it comes to the best CPU for gaming for our next build.

Intel has managed to stay competitive through AMD's successive performance improvements to Zen thanks to its dominance in gaming. While AMD was making everything else to do with computing a miserable story for Intel, it still had that one flag to cling to. That has now gone. While Zen 3 doesn't dominate Intel in gaming quite in the way that AMD optimistically hoped it might, there is now basically nothing between the two. The fact that this chip can do lots of other processor-intensive tasks and game just as well as Intel's finest means that Intel isn't really an option for anyone wanting serious performance.

There are caveats, though—there always are. That performance doesn't come cheap. AMD is no longer the underdog, and it shows. This Ryzen 9 5900X will set you back a cool $549. That's on a par with Intel's top chip, the Core i9 10900K (which launched at $499, but has seen its price drift upwards since). And while we'll be quick to point out that this has more cores than Intel's 10-core offering, and that, yes, this performs much better in serious workloads, there's no getting away from the fact that this is an expensive chip.

The most fundamental change is how the cores are configured. Zen 2 has up to four cores per core complex (CCX), so that each four-core cluster has access to 16MB of L3 cache. If a core from one cluster wants to access the L3 cache from another cluster it has to communicate with that cluster through the I/O die using the Infinity Fabric, which is much slower than accessing that local L3 cache. In Zen 3, AMD has moved to an eight-core design instead. Now all eight cores can access 32MB of L3 cache directly, and don't need to go through the I/O die to do so. This also means that core-to-core access is much quicker as well, and will mean there are situations where this change alone can offer significant performance improvements. There may still be times in dual-chiplet CPUs where one cluster wants to access the L3 cache, or communicate with the cores of another cluster, and it can absolutely do that via the Infinity Fabric, but this shouldn't happen anywhere near as often in normal usage.

Now the important bit: Performance. A processor can have the cleverest architecture around, but unless it delivers, what's the point? Well, luckily for both AMD and us, it absolutely delivers. Whether you're looking at serious number-crunching for video encoding and 3D rendering, or for gaming, the Ryzen 9 5900X absolutely delivers. This thing is a beast.

This alongside an Nvidia GeForce RTX 3080 makes for a formidable core that can handle 4K easily, and also turn its hand to more productive tasks without really breaking sweat. It'll surely play nice with the upcoming RX 6000-series GPUs, too. Throw in a quality next-gen SSD, a decent motherboard and some quality RAM, and you've got a build that will easily outlive the PS5 and the Xbox Series X. It'll cost a lot more, but it can do so much more.

The key factor in this is that AMD has wrestled the gaming performance crown off Intel. And even if it isn't quite a knockout—more a win by points if we stick with that metaphor—it doesn't diminish the fact that the last cry of Intel diehards has vaporized. It doesn't matter if you side with Intel or AMD when it comes to gaming, they're both just as capable. And given the overall package from AMD, that makes this the better chip. **–ALAN DEXTER**

RAM BENCHMARKS

	AMD Ryzen 9 5900X	AMD Ryzen 9 3900XT	Intel Core i9-10900K
Cinebench R20 Single (Index)	**638**	528	534
Cinebench R20 Multi (Index)	**8,348**	7,205	6,373
X264 v5.0 Video Encoding (avg fps)	**75.1**	63.58	51.81
SiSoft Sandra Memory Bandwidth (GB/s)	37.6	**37.82**	33.9
3DMark Time Spy (Index)	14,100	13,985	**14,261**
Civilization VI AI Test (seconds)	6.57	**6.47**	6.8
Total War: Three Kingdoms @ 1080p	**154**	132	148
Far Cry New Dawn @ 4K	83	79	**85**

Best scores in bold. Our test bed consists of an Gigabyte X570 Aorus Master, 16GB Thermaltake DDR4 @ 3600, an Nvidia GeForce RTX 2080 Ti, 2TB Sabrent Rocket PCIe 4.0 SSD, and a Corsair H115i RGB Pro XT. All games were tested on the high profile.

VERDICT
9
KICK ASS!

AMD Ryzen 9 5900X

➕ **RISING UP** Awesome performance throughout; fast and efficient architecture; PCIe 4.0 support.

➖ **SCAMPERING AROUND** Expensive; no cooler as standard.

$550 www.amd.com

SPECIFICATIONS

Cores / Threads	12 / 24
Base / Turbo Clock	3.7 / 4.8 GHz
Architecture	Zen 3
Lithography	TSMC 7nm+
Memory Support	DDR4 3200 MHz
PCIe Support	16+4+4 PCIe 4.0
Integrated Graphics	N/A
TDP	105W

AMD Radeon RX 6800 XT

Memory, cache, and killer clocks, but it falls short

IT SEEMS LIKE every new generation of GPU from AMD is supposed to be the chosen one. Navi, Vega, Polaris, Fiji, Hawaii, Tahiti, Cayman—if those names don't mean anything to you, they're the codenames for everything from HD 6000 up through to RX 5000. Many were good, but few were unequivocally great. But this time is going to be different, or so the story goes. Could RDNA 2 and Big Navi finally put AMD ahead of Nvidia at the top of the GPU stack?

After seeing the RTX 30-series Ampere GPUs launch over the past few months, we were skeptical. Nvidia doubled down on FP32, Tensor core, and ray-tracing performance. Leaked AMD specs for Navi 21 looked decent, but nowhere near enough to take down Ampere. Then AMD started talking about its new Infinity Cache, and we remembered the hype around Vega's High-Bandwidth Cache Controller: much ado about... well, not nothing, but not much either.

Let's be clear—Infinity Cache actually is different. Fundamentally, it seems simple: Put a huge chunk of L3 cache on the chip to hold the various framebuffers and eliminate a lot of the memory congestion, thereby boosting performance and efficiency. Sometimes, the simple answers are best. Peak Infinity Cache bandwidth can break 2TB/s, and while the RX 6800 XT only has 512GB/s of GDDR6 bandwidth, in practice it performs much better. Getting the GPU to clock at upward of 2.25GHz helps as well, and with overclocking we routinely saw 2.4-2.5GHz on the 6800 XT. That's the fastest we've ever seen from a GPU on air cooling, and power use isn't even bad.

Speaking of theoretical performance, Nvidia's RTX 3080 checks in at 29.8 TFLOPS of FP32, with some of that shared by the concurrent 14.9 TOPS of INT32 capability. RX 6800 XT tips the scales with a comparatively scrawny 20.7 TFLOPS of FP32, which is shared with INT32 operations. How could AMD's latest star even hope to compete? And yet, it does. Mostly anyway.

Across an extended test suite (we're only able to show part of it in the tables), the 6800 XT and RTX 3080 trade blows, each winning about half of the games tested. Overall, it's pretty close to a dead heat—except when we add in ray tracing, and then the 6800 XT stumbles. Badly.

We ran 10 DirectX Raytracing (DXR) benchmarks, which is where the composite score in the table comes from. AMD's 6800 XT came out with exactly one minor win: *Dirt 5*, with beta DXR support—and it's an AMD promotional title that even without DXR strongly favors AMD right now. Plus, the ray-tracing effects are hard to even spot. In other DXR tests, like *Control*, *Call of Duty*, *Boundary*, *Fortnite*, and more, the RTX 3080 is 20 to 40 percent faster. And that's without turning on DLSS quality mode, which we think looks better, while boosting performance of Nvidia GPUs another 20 to 40 percent.

What you think of the new RX 6800 series largely comes down to what you think about ray tracing and DLSS. Both have a lot of untapped potential, and we're very much looking forward to checking out the DXR and DLSS enhancements to *Cyberpunk 2077*—that could finally be ray tracing's killer app (maybe).

Unfortunately, all of the latest graphics cards remain extremely supply constrained, so buying any of them may prove difficult. AMD also has supply issues for its new Zen 3 processors. The 5900X and 5950X only use about 160mm square of 7nm die area, while the Navi 21 GPU measures over three times that size—not to mention the costs of cooling, GDDR6 memory, and all the other extras that go into a graphics card. Short term, AMD would be better off producing and selling more Ryzen 5000 chips than Radeon RX 6000. Which means supply isn't likely to improve any time soon. **–JARRED WALTON**

VERDICT 8

AMD Radeon RX 6800XT

+ CACHING IN 16GB GDDR6; 128MB cache; 2.4GHz overclocks.

− SELLING OUT Weak RT performance; no DLSS or Tensor cores.

$650 www.amd.com

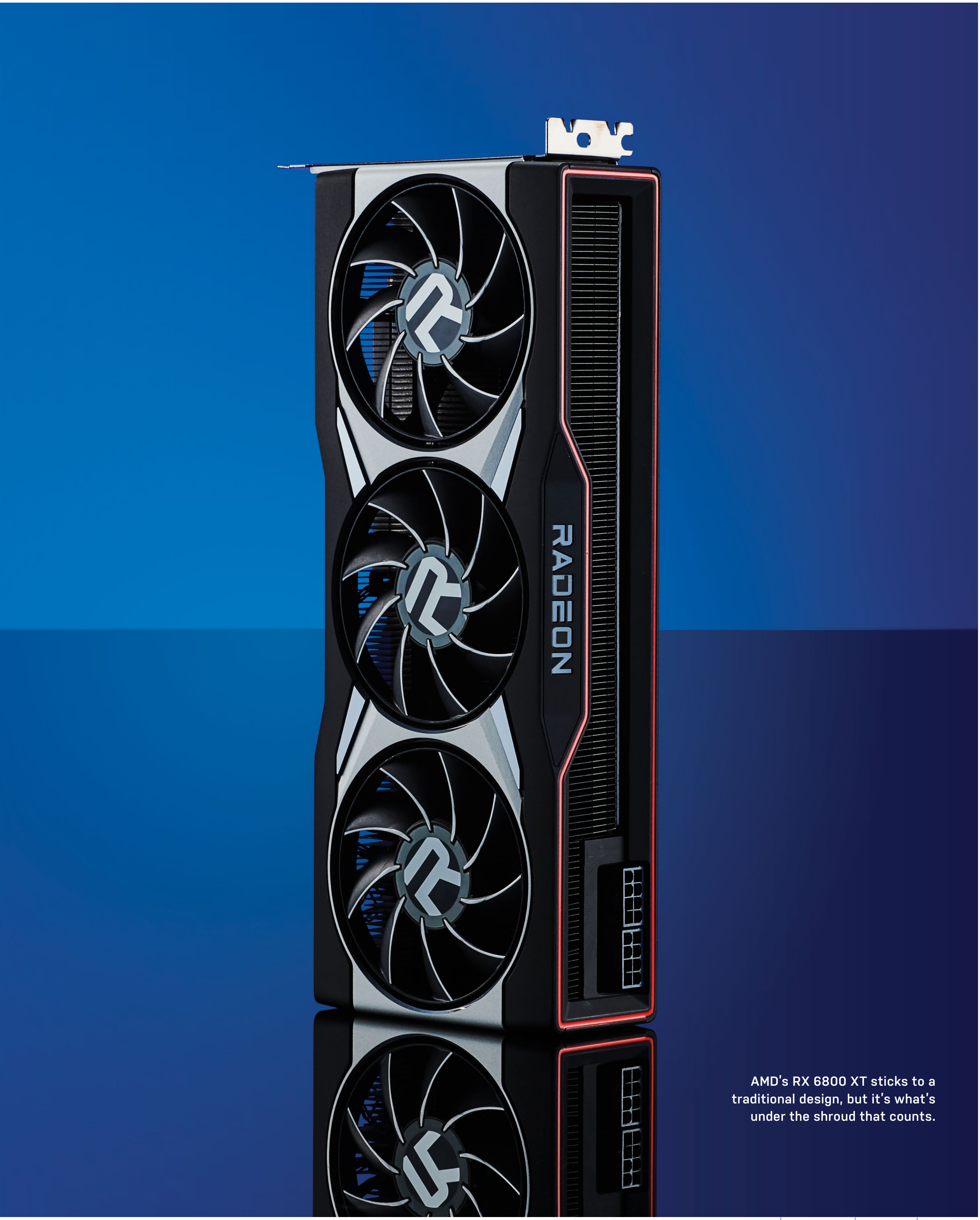
GPU BENCHMARKS

	AMD Radeon RX 6800 XT	Nvidia GeForce RTX 3080 FE	Nvidia GeForce RTX 2080 Ti
Borderlands 3 (Min/Avg fps)	**106/122**	93/111	74/85
Tom Clancy's The Division 2 (Min/Avg fps)	106/128	**109/131**	84/101
Far Cry 5 (Min/Avg fps)	105/138	**115/148**	109/135
Red Dead Redemption 2 (Min/Avg fps)	84/102	**85/105**	70/85
Shadow of the Tomb Raider (Min/Avg fps)	**117/153**	110/148	92/119
Strange Brigade (Min/Avg fps)	168/235	**203/258**	159/198
3DMark: Port Royal (Min/Avg fps)	36/43	**44/53**	34/41

Best scores are in bold. All testing conducted with Core i9-9900K, MSI MEG Z390 ACE, 2x16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores are at 1440p ultra and show 'minimum' 99th percentile frametime fps and average fps.

SPECIFICATIONS

GPU / Architecture	Navi 21 XT
Lithography	TSMC N7
Core / Boost Clock	2,015 / 2,250
Memory	16GB
GPU Cores	4,608
Single Precision	20.7 TFLOPs
TDP	300W
Display Connectors	DisplayPort 1.4, HDMI 2.1



AMD's RX 6800 XT sticks to a traditional design, but it's what's under the shroud that counts.

Nvidia GeForce RTX 3070 Founders Edition

RTX 2080 Ti performance at half the price?

THE GEFORCE RTX 3070 is round three of Nvidia's Ampere architecture. All of the core features are present, and yet Nvidia dials things back quite a bit from the earlier outings. We weren't expecting RTX 3090 levels of performance for $500. Still, having seen what the RTX 3080 and 3090 bring to the table, this is definitely a big step down.

In a vacuum, the 3070 basically delivers RTX 2080 Ti performance at half the price, which sounds like a bargain. But the 3080 has 70 percent more memory bandwidth and 45 percent more theoretical computational power, and ends up beating the 3070 by about 35 percent overall. It also costs 40 percent more, but nearly linear scaling of performance with price is far better than the usual diminishing returns we see at the top of the GPU stack—just look at the 3090, which more than doubles the 3080's price for only 15 percent more performance.

Our biggest concern with the 3070 is the VRAM. 8GB became the mainstream and high-end standard back in 2016. Four years later, it's starting to feel like the bare minimum for a mainstream card, never mind a high-end offering. Now that AMD has launched its RX 6800 series (see the 6800 XT review on page 74), with 16GB of higher clocked GDDR6 across the lineup, 8GB of 14Gbps memory feels downright limiting.

It may not matter too much in today's games. You can comfortably run at 1440p or 4K with maxed out settings in most current titles. But there are some newer releases like *Dirt 5* and *Watch Dogs Legion* that can exceed 8GB and start to thrash data with system RAM. The PlayStation 5 and Xbox Series X both have 16GB of total RAM as well, so 8GB might become more of a concern over the coming years.

What we're saying is we don't like being locked out of certain settings. We want to wander free and in the clear, without giving much thought to VRAM. After seeing 10GB of GDDR6X on the 3080, and a monstrous 24GB of GDDR6X on the 3090, we were hoping to get a bit more than the same memory configuration that we've had on everything from the 2060 Super up through the 2080. Push settings too far and the lack of VRAM can put the kibosh on your gaming fun. That's why we'll probably see an RTX 3070 Ti with 16GB in the coming months, which might be worth waiting for.

POTENT TO A POINT

The 3070 is still a potent performer, blasting through our test suite at 1080p and 1440p, and sometimes even 4K. Turn on ray tracing, however, and performance tanks. *Control* and *Call of Duty: Black Ops Cold War* are the only RT-enabled games in our table, but we tested eight other RT games for the composite ray-tracing score. Without DLSS, only 1080p is really viable on the RTX 3070, but DLSS can boost performance by 30 to 80 percent, depending on the game and settings—and it's available in games that don't use ray tracing as well.

For games that lack ray tracing and/or DLSS, AMD's RX 6800 is a reasonable alternative, normally leading the 3070 in rasterization performance. But AMD has no real answer to Nvidia's Tensor cores, which are useful for more than just DLSS. Nvidia Broadcast rocks for eliminating background noise from your recordings and video calls, and it can help with background removal and other effects as well. Nvidia will likely find other uses for the Tensor cores in the coming years.

The 3070 delivers good rasterization performance, better RT performance than the competition, and it has the added benefit of Tensor cores. That's at a lower price and power use than the RX 6800, making it the better long-term prospect for most gamers. If you can manage the bump up to the 3080, though, it's the best option. **–JARRED WALTON**

GPU BENCHMARKS

	Nvidia GeForce RTX 3070 FE	AMD Radeon RX 6800	Nvidia GeForce RTX 2070 Super
Borderlands 3 (Min/Avg fps)	73/85	**89/103**	55/63
Tom Clancy's The Division 2 (Min/Avg fps)	83/99	**90/109**	61/72
Far Cry 5 (Min/Avg fps)	102/129	**105/135**	87/103
Red Dead Redemption 2 (Min/Avg fps)	66/80	**73/90**	51/59
Shadow of the Tomb Raider (Min/Avg fps)	90/114	**101/131**	72/95
Strange Brigade (Min/Avg fps)	**153**/192	139/**198**	115/142
3DMark: Port Royal (Min/Avg fps)	**32/37**	30/35	23/27

Best scores are in bold. All testing conducted with Core i9-9900K, MSI MEG Z390 ACE, 2x16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores are at 1440p ultra and show 'minimum' 99th percentile frametime fps and average fps.

VERDICT

8

Nvidia GeForce RTX 3070 Founders Edition

+ **GOALS** RT, DLSS, and Tensor; efficient architecture; attractive pricing.

− **GAOLS** No GDDR6X; 8GB feels stingy; rasterization performance.

$500 www.nvidia.com

SPECIFICATIONS

GPU / Architecture	GA104 / Ampere
Lithography	Samsung 8N
Core / Boost Clock	1,500 / 1,725
Memory	8GB GDDR6
GPU Cores	5,888
Single Precision	17.6 TFLOPs
TDP	220
Display Connectors	DisplayPort 1.4a, HDMI 2.1

The RTX 3070 Founders Edition is more compact than its bigger siblings, with a traditional fan configuration and no GDDR6X.

The EliteOne's clean aesthetic fits into any professional environment.

HP EliteOne 800 G5

All for one and one for all

ALL-IN-ONE PCS can be a tricksy business. Towers with discrete monitors are generally considered the norm, and any AIO computer draws obvious comparisons to both Apple's successful iMac range and desktop-replacement Windows laptops. They also have inherent limitations imposed on them by their small, screen-sized form factor; integrated graphics are usually the only option, and physical connectivity frequently takes a hit.

HP's new AIO, the EliteOne 800 G5, is all business. Costing $1,400 (for our review SKU specifically), this is a professional machine, well-suited to a home office environment. The brushed silver finish is unobtrusive, and the 23.8-inch monitor has a pleasingly small bezel. Being an AIO system, it has a small footprint, with just a weighted metal rectangle as its base, upon which the rotating monitor arm and the screen itself are mounted.

It has to be said that the EliteOne is remarkably easy to set up. It's truly a plug-and-play affair, with the entire assembly slotting together without any tools required, and only a single three-pin kettle cable needed to power it all up. Included in the box is a wireless Bluetooth "Business Slim" mouse and keyboard combo from HP, which connect instantly with the touch of a button once their shared USB dongle is plugged in at the rear of the display. It's a nice inclusion that makes setup a breeze, but it should be noted that the mouse and keyboard are older models and do feel a bit unimpressive nowadays.

Once you've got your speedy setup out of the way, you'll be able to enjoy the EliteOne's bright and colorful display. It's a 1080p WLED-backlit panel, large enough for work or entertainment, and the EliteOne also comes with a pricier touchscreen variant for those who prefer a more tactile display. We weren't blown away by the screen, but it's certainly a good choice of display—better than the 17-inch FHD panels found on the many home office laptops.

The audio on offer is surprisingly good. As with other premium HP products, it's handled by industry veteran Bang & Olufsen, with integrated stereo speakers sitting behind a patterned grille beneath the display. It's not going to beat a proper speaker setup or a pair of audiophile-approved headphones, but it's better than the built-in speakers you'll find on the average monitor. The maximum volume is quite impressive, with little distortion.

In broader performance terms, the Intel Core i5-9500 processor in this AIO struggles in some areas, while excelling in others. Single-core tasks are a breeze, but multi-core workloads don't fare quite as well. With only 8GB of RAM and no discrete GPU, HD gaming and other 3D-rendering tasks are pretty much out of the question. For your standard office work, though, it manages just fine, keeping numerous Chrome tabs or spreadsheet columns up and running with ease. It does all this quietly, too, with barely any fan noise even under duress. The rear panel where the CPU is housed got a little warm during some of our benchmarks, but never for long.

A high-speed M.2 SSD makes file transfers and load times nice and fast, with read speeds approaching 3.5GB/s. Our model had a 256GB drive, which might be enough for some, but we'd advise opting for the 512GB or 1TB variants. Both the drive and memory are consumer-upgradable, but it's more of a hassle to do so than with a typical laptop.

Overall, we do have to ask if this AIO is really any better than having a laptop set up for working at home. Yes, the pop-out disc drive and webcam are cool, but these features can be found on laptops. The main advantage here is the quiet running and the bigger, brighter screen, since the EliteOne's performance figures certainly won't trouble any laptops around the $1,400 price point. Ultimately, while the EliteOne isn't terrible, you could pick up a more powerful and portable machine without making such a big dent in your wallet. **–CHRISTIAN GUYTON**

VERDICT
7

HP EliteOne 800 G5

+ ONE Quick and easy setup; silent running; decent audio.

− ZERO Expensive; the included mouse and keyboard are meh.

$1,400, hp.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	541	979 (81%)
CrystalDisk QD32 Sequential Read (MB/s)	540	3,445 (538%)
CrystalDisk QD32 Sequential Write (MB/s)	372	1,414 (280%)
3DMark: Fire Strike Ultra (Index)	1,183	1,173 (-1%)
Rise of the Tomb Raider (fps)	5	6 (20%)
Total War: Warhammer II (fps)	3	6 (100%)
Tom Clancy's Ghost Recon: Wildlands (fps)	2	3 (50%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i3-8100, 8GB of Team Vulcan DDR4 @ 2400, and a 120GB Kingston SSDNow UV400. All tests were performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	Intel Core i5-9500 @ 3.0GHz
Graphics	Intel UHD Graphics 630
RAM	8GB DDR4 @ 2666MHz
Screen	23.8-inch IPS WLED-backlit 1080p widescreen
Storage	256GB M.2 NVMe SSD
Ports	1x HDMI, 1x DisplayPort 1.2, 4x USB 3.1 Gen2 Type-A, 1x RJ-45 headphone jack
Connectivity	Wi-Fi 6, Bluetooth 5
PSU	210W 92% efficiency integrated power supply
Optical Drive	HP 9.5mm Slim Blu-Ray/DVD/DVD-ROM writer double layer

Philips 279C9

A precision productivity package

IF YOU'RE IN THE MARKET for a monitor, it's hard to avoid all the hype. Dubious claims of HDR capabilities, ridiculously high refresh rates—it all seems rather tangential to, you know, getting something worthwhile done on your PC.

We love PC gaming, but too much of what dominates the current monitor mindspace is gaming-centric, which is where the new Philips 279C9 comes in. It doesn't really care about gaming.

That isn't to say the 279C9 is a total dud when it comes to leisure—far from it. But it does offer what you might call a finely-tuned precision-productivity package. The core highlights involve a quality 27-inch IPS panel with native 4K 3,840 x 2,160 resolution, plus USB-C connectivity with support for device charging.

Strictly speaking, the 279C9 is HDR certified. However, we're talking VESA DisplayHDR 400, which doesn't make for a genuine HDR experience.

Other details of note include 65 watts of charging power for USB Type C devices. That means you can hook up via USB-C and drive the display, charge your laptop, and connect peripherals to the display's USB hub, all with a single cable. It's bliss. Once you've gone USB-C, you really won't want to go back to that rats' nest of cables coming out of your notebook PC.

What else? Well, this is a productivity panel, so the refresh rate is pegged at 60Hz, brightness tops out at 400cd/m2 and contrast is quoted at 1,300 to 1. It's all predictable for a contemporary IPS panel. For the record, it also supports AMD's FreeSync adaptive refresh technology.

As for color coverage, it's arguably a weak area. Philips doesn't quote coverage of several workflow-critical spaces, including DCI-P3 or AdobeRGB. The only gamuts specified are sRGB at 109 percent coverage, and NTSC at 90.7 percent. That implies middling rather than excellent color fidelity.

Back in the real world, however, even without exotic color coverage, this is a very fine display. Out of the box, it's an absolute peach—punchy, vibrant, and just plain gorgeous. The 4K resolution squeezed into a 27-inch panel makes for very high levels of detail. Granted, it probably doesn't qualify as a true high-DPI experience. But it's as close as you're going to get for anything resembling sensible money.

And forget about the dubious HDR rating. Just focus on the fact that this is a very fine SDR monitor. Philips's default factory calibration is also good, with little to no evidence of compression at either the white or black end of our test scales.

The viewing angles are likewise about as good as it gets, while contrast performance is top drawer for an IPS panel. A little IPS glow is visible, but not enough to spoil the show. As for pixel response, three levels of user-configurable overdrive are available. In the two fastest modes, some overshoot and inverse ghosting is evident. But the lowest level makes for decent response.

What's more, we detected no discernible input lag. Add in that FreeSync support, and you have a pretty nice gaming panel, provided you don't demand high refresh. Factor in the super-slim bezels, plus the quality all-metal stand with a full range of adjustments, and you get a high-quality device that feels more expensive than it is.

The catch is that relatively limited color coverage. It's what prevents it from offering true pro-grade content creation capability. But then that's fine at this price point. For its intended remit, the Philips 279C9 absolutely nails it. –**JEREMY LAIRD**

VERDICT
9
KICK ASS!

Philips 279C9

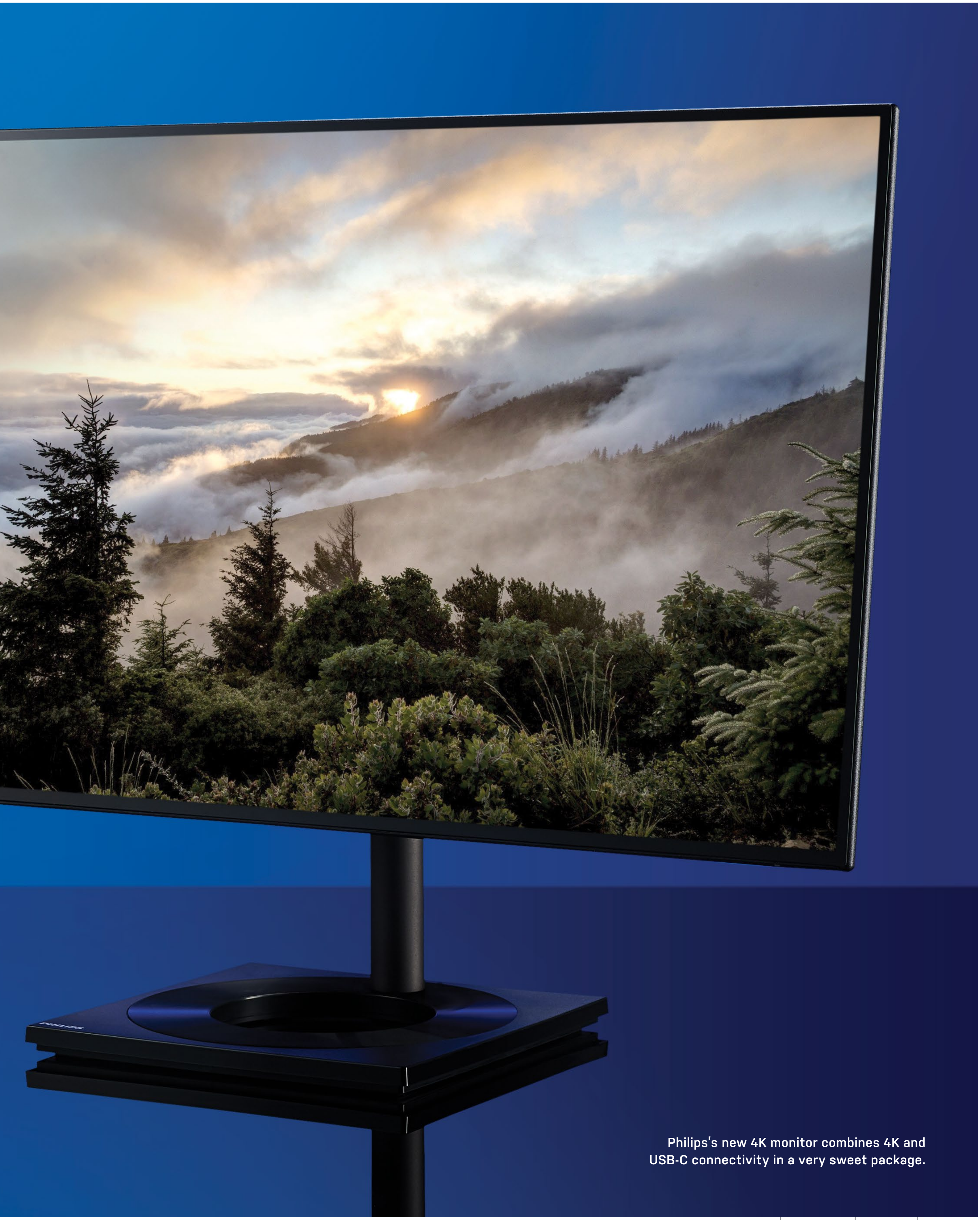
TARGET ACQUIRED Luscious 4K IPS panel; slick USB-C connectivity.

COLLATERAL DAMAGE Almost nothing given the price point and remit.

$499 www.philips.com

SPECIFICATIONS

Panel size	27-inch
Panel type	IPS
Resolution	3,840 x 2,160
Brightness	400cd/m2
Contrast	1,300:1
Pixel response	5ms
Color coverage	109% sRGB, DisplayHDR 400
Refresh rate	60Hz
Vesa	100mm x 100mm
Connectivity	DisplayPort 1.4, 2x HDMI 2.0, 1x USB C with 65W charging



Philips's new 4K monitor combines 4K and USB-C connectivity in a very sweet package.

If this editor had an E-ATX build, it'd be in this chassis.

be quiet! Silent Base 802

Taking modular customization to the extreme

LOOK AT THAT CASE THERE, crisp, standing pristine in the light, the soft-lit gradient running down the front panel, glinting off the top left of that tempered glass. It's modest, refined, and simple, at least at first glance. Our photographer's skill is nothing to be sniffed at, and yet even with his brilliance, the Silent Base 802 still gives nothing away. It's clearly just another black box from be quiet! complete with a tempered-glass side panel, and a few other basic features chucked in for good measure, right? Not worth the time of day to review, surely?

Well that's the brilliance of this case. It is almost akin to a sleeper chassis: It's so good, and yet from first appearances, there's absolutely nothing really that gives that brilliance away. The key lies in the modularity of this thing, or more importantly the customization on offer. In fact almost every part of this case can be removed, or swapped, or flipped, or reconfigured in such a way that you can do something entirely different with it each and every time.

Take the motherboard tray: You can flip it entirely and turn it into an inverted build; you can swap the glass side panels over, the hard drive trays over, and the PSU cover can still stay on the bottom, to keep a clean-looking aesthetic. Then there's the front and roof panels, both of which are completely removable. In fact be quiet! includes as standard an additional air-filtered mesh front panel as well, for better airflow (albeit at the sake of noise). Then there's the top cover, which features three different configurations. Either entirely sealed off, covered with a mesh filter, or open with perforated holes for maximum airflow again. Inside you've got access to a vertical GPU slot (albeit for 2.5-slot cards only), support for no fewer than seven 3.5-inch drives (with three caddies included), and mounting locations for 15 2.5-inch SSDs as well (with seven caddies included as standard).

Regular air-cooling features include support for up to three 140mm fans in the roof, three 140mm fans in the front, and one 140mm fan in the rear, with three be quiet! Pure Wings 3 140mm fans included pre-installed (two in the front, and one in the rear). What's perhaps the coolest feature of this chassis, however, is the fact that you can actually install an additional 140mm fan on the PSU shroud itself, which helps to pull cool air up through the ventilation in the base of the case, and blast it up into the GPU or HDDs above it. That's seriously smart.

Of course, with as much support for fans as that, you also get some seriously beefy liquid-cooling support too, with up to a 420mm radiator in the front, a 360mm radiator in the roof, and a 140mm radiator in the rear. And there's plenty of room for mounting reservoirs, and maximizing your tubing run efficiency too.

For the noise-conscious, the 802 also features sound insulation mats on the solid front and side panels, and there's also a four-step fan controller, with support for up to six fans baked into the front I/O. Speaking of which, other connectivity includes USB 3.2 Type C, USB 3.2 Type A, a power button, and some audio passthroughs for good measure.

This thing is a monster. At first glance it looks just another chassis, but it's only when you start to dig under the surface that you identify just how much potential this thing has. If you've got a build in mind—a high-end gaming system, an air-cooled workstation, a liquid-cooled Dream PC, or a huge NAS server—there's no doubt the Silent Base 802 can do it, and do it well. **–ZAK STOREY**

VERDICT

9

KICK ASS!

Be quiet! Silent Base 802

+ GLORY Extreme customization; innovative new ideas; fan controller as standard; impeccable price; versatile.

− GORY Vertical GPU mount could be bigger.

$170 www.bequiet.com

SPECIFICATIONS

Motherboard Support	E-ATX (10.82 inches), ATX, M-ATX, ITX
2.5 / 3.5-inch Support	15 / 7 (7 / 3 included)
Max Radiator Support	420mm Front, 360mm Roof, 140mm Rear
Fan Support	3x 140/120mm Front, 3x140/120mm Roof, 1x 140mm Rear, 1x 140/120mm PSU Shroud
Dimensions	21.2 x 11.1 x 21.8 inches
Graphics Card Clearance	11.3 / 17.0 inches (with / without HDD caddies)
CPU Tower Clearance	7.28 inches

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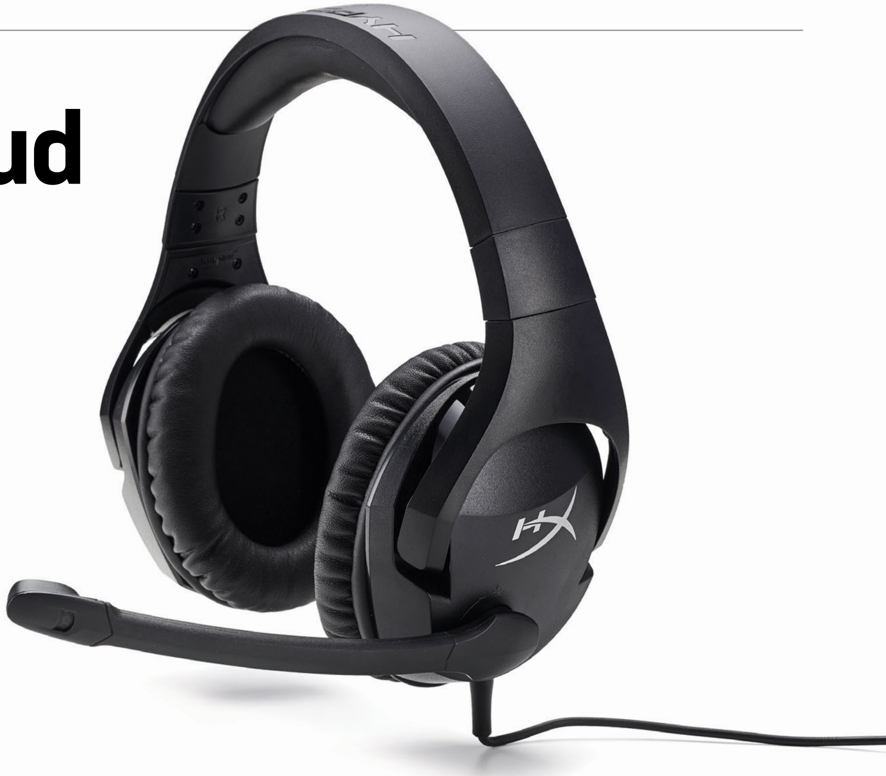
HyperX Cloud Stinger S

Sting like a bee



HYPERX'S HEADSETS are frequently a good bet, and the new Stinger S addition to its Cloud line is no exception. The Stinger S goes in the opposite direction to the Stinger Core, which was a cheaper alternative to the original Stinger. At $60, the Stinger S is more expensive, edging its way into premium headset territory, but it has a lot to offer for the price.

Let's start with the audio quality. Unlike the 40mm neodymium drivers found in the Core models, this headset has the original Stinger's high-quality 50mm drivers, bringing a broader frequency response that delivers clear, crisp highs and bassy lows. It's a remarkably balanced sound profile, and while it won't blow away any serious audiophile, it's certainly sufficient for both gaming and music or podcasts.

The big draw here is the virtual 7.1 surround sound HyperX has touted in several of its more recent headsets. It's powered by HyperX's own NGENUITY software, and while it isn't "true" surround sound as such, it certainly works well. For games that can support 3D audio, pinpointing the physical locations of sounds works a treat. We started out skeptical that 7.1 surround sound would really make us better at online shooters, but after using several of these headsets, we've had to eat our words. Getting the drop on an opposing player by successfully tracking the sound of their footsteps or reloads feels great.

The solid audio is paired with an excellent flip-down microphone, which is muted automatically when swiveled up away from your mouth. Its unidirectional polar pattern picks up speech by the wearer well, while noise-cancelling tech keeps background disturbances from ruining the experience for your squadmates. It's not the fanciest mic we've ever seen, sure, but it allows for good clarity of communication during co-op games.

In terms of physical design, the Stinger S doesn't do much to develop on previous iterations. The earcups are memory foam wrapped in a soft, breathable leatherette, which combined with the relatively low weight makes for a very comfortable headset for extended gaming sessions. The earcups rotate 90 degrees, allowing them to rest flat against your chest if you lower the headphones around your neck for a quick break. The skinny 3.5mm cable comes with a USB adaptor, and is 2.5m long, preventing any impedance during use.

Overall, the construction is mostly plastic, with a brushed black paint job and a white HyperX logo on the outside of each earcup. We do appreciate the dark, tidy design; there's no colorful trim or unnecessary RGB to be found here. Although steel sliders are hidden inside both sides of the headband to extend to fit any head, the Stinger S does feel a bit flimsy in comparison to more expensive headsets. Part of this is down to the lightweight design, but the brittle plastic casing means we can't help but feel that this headset might not be the most durable among its peers. A volume slider located on the underside of the right earcup feels similarly cheap.

The NGENUITY software that accompanies the Cloud Stinger S is instrumental in implementing the virtual 7.1 surround sound, but unfortunately it's rather limited in other areas. Although it allows for huge customization of HyperX keyboards and mice, it definitely doesn't allow for as much audio-tweaking potential as we'd like. The software is still in beta, however, so this is something that might improve in the future.

The Cloud Stinger S is, on the whole, a good headset for the price. While it might be somewhat feature-light compared to other premium offerings, it performs well and is comfortable to use. We'd like to see a slightly sturdier build quality, but for $60 it's fairly hard to argue with. The quality of the virtual surround sound elevates this headset for online gaming, and while it's not the cheapest 7.1 headset, we'd wager it's one of the most comfortable. **–CHRISTIAN GUYTON**

VERDICT
8

HyperX Cloud Stinger S

+ **HORNET** Balanced soundscape; comfortable and lightweight; good microphone.

− **MAYFLY** Limited customization; doesn't feel so durable.

$60, hyperx.com

SPECIFICATIONS

Driver Type	50mm neodymium magnet
Frequency Response	18Hz–23kHz
Sensitivity	-40dBV
Design Style	Circumaural, closed back
Microphone Type	Unidirectional noise-cancelling electret condenser
Connection Standard	3.5mm/USB
Battery Life	N/A
Weight	0.61lb

SteelSeries Aerox 3 Mouse

SteelSeries enters the ultra-light scene with the Aerox 3, but is it a hit or a miss?

STEELSERIES is no stranger to the gaming peripheral scene, but this is its first foray into the ultra-light mouse sector. Ultra-light mice have increased in popularity in recent years, and love them or hate them, they don't seem to be going anywhere anytime soon.

The Aerox 3 we have here is a wired mouse, but the rather nice, silky smooth USB Type C cable can be removed, presumably so that SteelSeries can use the same shell for both the wired and wireless version. The mouse is somewhat on the smaller side, and large-handed folks might struggle, especially with a palm grip—fingertip or claw grips are preferred and recommended. The shape is nice and familiar, and the six programmable buttons are easily accessible. All of the buttons and the scroll wheel are of good quality, and we have no real complaints there. The structure of the mouse leaves a little to be desired, however. Pushing down on the mesh part of the mouse will cause the shell to bend enough to activate the CPI button. It does take a more than the usual amount of downforce to create this issue, but it became apparent on the first day of testing.

The sensor in the Aerox 3 is the TrueMove Core, which seems to be a Pixart 3331 variant and is a great sensor for cheaper mice. SteelSeries actually uses the same one in the Rival 3, but that comes in at half the price. We would have preferred to see the TrueMove 3 at $60, like in the Rival 310, but that might be a bit much to ask, and in all honesty the difference isn't that huge unless you're a top-tier gamer. The Core tracked very well in our testing and worked fine on all our usual surfaces, and that is what really matters here.

In terms of aesthetics, the Aerox 3 is very similar to the majority of other ultra-light mice, and for those worried about dust, sweat, or liquids getting into the honeycomb structure, have no fear—it is IP54 rated, which means it is resistant to dust and fluids.

LIGHT UP THE LIGHTWEIGHT

The software and lighting are really good. As well as the usual macro editor and configuration options, which are easy to use and intuitive, there are three lighting zones that can be customized individually. The strange thing is that unless SteelSeries Engine is running, the settings don't sync with the mouse, and if you close the program completely the mouse reverts back to default colors. The CPI settings still work, however, so it is strange that the lighting doesn't. This is particularly noticeable if you restart the computer, because until SteelSeries Engine loads up, the mouse will either be on your CPI color setting or just going through rainbow colors. As soon as the software opens, it will change to your custom colors.

In conclusion, then, the Aerox 3 is a rather nice mouse, but it isn't without its issues. The RGB lighting is vivid, and the customization options are plentiful, but not saving these settings to the mouse is a little strange. This might be changed in the future in a firmware update if there is enough memory on the mouse to allow it.

The mouse is comfortable and certainly lightweight, though perhaps a little more strength in the shell would have been preferable. The software is easy to use, and the sensor is good enough for the majority of your computing needs, but at this price point, when competing against so many other similar mice, there are better sensors on the market that other brands take advantage of.

It ticks so many boxes, though, and unless you're being really picky, you will likely be pleased with your Aerox 3 purchase, especially if you can get it on offer. **–DAVE ALCOCK**

VERDICT **8**

SteelSeries Aerox 3

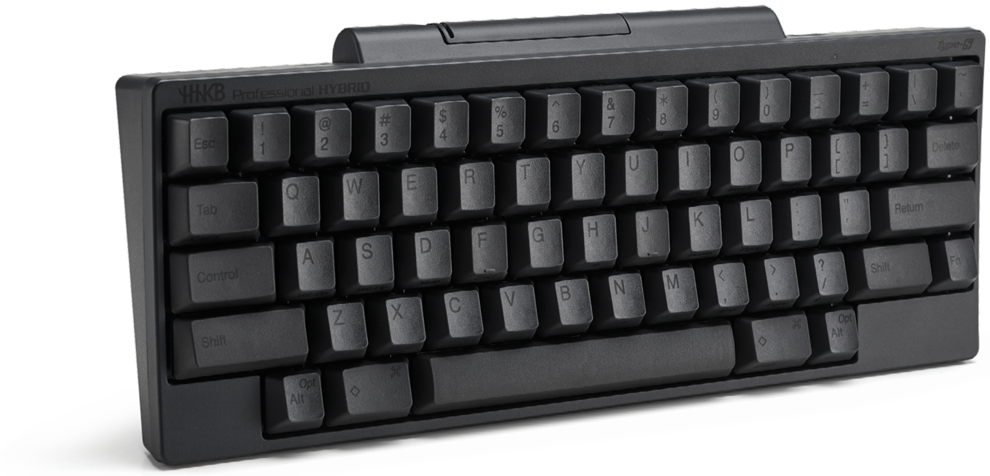
+ HARDENED STEEL Great software; very lightweight; comfortable; excellent lighting options.

− WET FLANNEL Flimsy shell; lighting doesn't save to mouse; expensive.

$59.99, www.steelseries.com

SPECIFICATIONS

Sensor Model	SteelSeries TrueMove Core
Max Sensitivity	200–8,500 in 100 CPI Increments
IPS	300
Acceleration	35 G
Programmable Buttons	6
Connection Standard	USB Type C to USB Type A 6ft
Battery Life	N/A
Weight	0.13 lbs



Happy Hacking Pro Hybrid Type-S Keyboard

$337 for this beauty, but why?

HAPPY HACKING Keyboards (HHKBs) are often seen as the holy grail of keyboards for developers, coders, and sys admins, but you'd be right to be hesitant on dropping that kind of cash on what seems like such a basic board. What can possibly make it cost so much?

First and foremost, Topre switches. These are electrocapacitive switches that are a dream to type on. They're like typing on clouds. If you've never used Topre switches, it's worth trying them just to feel how soft switches should be done. Topre switches are made by a single company in Japan, and the price of them is eye-watering. Topre switches have a conical spring underneath a rubber dome. The plunger compresses the dome and spring until it makes it actuate. This kind of switch eliminates key chatter or double switch-presses, and they are also far more consistent in terms of feel than standard switches. The Topre switches in the HHKB Pro Hybrid Type-S have a switch weight of 45cN with a 3.8mm travel. They are very tactile, and the "Type-S" part of the name signifies that these switches also have a dampener to make them quieter, which if you put it next to the standard HHKB makes a big difference.

Trying to compare these switches to any others is rather hard, but think of a Cherry MX Brown, but instead of a snap, it is more of a smooth bump that slightly increases in intensity until the actuation point. The HHKB Topre switches have a circular plunger rather than the cross shape you see with Cherry MX style switches. This means that there are very few keycap sets that will fit it, and those that do are very expensive because of it.

The second main difference between a HHKB and the majority of other keyboards is the layout. The Ctrl keys have been relocated to where Caps Lock usually is, just like on early 80s IBM boards. Caps lock is removed completely (sorry keyboard warriors!), and the FN key is moved up a row too. At default, the Backspace key has also been changed to a Delete key, but there is a dip switch to revert this back—particularly useful when you're learning to type with the board, as for the first few weeks you will make many mistakes. All these changes, and a few smaller ones, were developed so that your hand position barely leaves the home row. For example, if you need to press Ctrl, which you do far more than caps lock, it is right under your left middle finger, rather than on the bottom row where you would usually have to shift your hand for. Small changes like this seem trivial, but when you're typing a lot it does make a huge difference, not just to typing speed but also posture.

All in all, the HHKB is a beautiful board. The Bluetooth on the HHKB Pro Hybrid is solid, and the standard AA batteries last a good amount of time and can be switched out easily with rechargeable ones (which we recommend). The board is small enough to be carried around with you, and as long as you don't need a numpad, RGB lighting, macros, and you can get used to the layout, you will likely be elated with it. Yes, the price of the HHKBs is very high, and you do feel a little bit hipster using it, but once you start to notice the benefits, you'll likely start to wish that all 60 percent boards had this layout. We love Topre switches but these are more of a personal preference. If you ever do see some in the wild, try them out, it might convince you to blow a $337-sized hole in your wallet. **–DAVE ALCOCK**

VERDICT

8

Happy Hacking Pro Hybrid Type-S

+ HAPPY HACKING Topre Switches; great Bluetooth connectivity for up to four devices; good battery life and easily replaceable; comfortable layout.

− NOT SO HAPPY Very expensive; not many keycap sets available; takes time to get used to the layout; no back lighting, keyboard can slide if you use the feet.

$337 www.hhkeyboard.us

SPECIFICATIONS

Form Factor	60%
Switch Type	Topre Electrostatic Capacitive Silent Key Switches
Switch Durability	50 million
Media Keys	N/A
Connection Standard	Detachable USB 2.0 / Bluetooth
Battery Life	2 months
Weight	19 oz (without batteries)
Dimensions	4.72 x 11.57 x 1.57 inches

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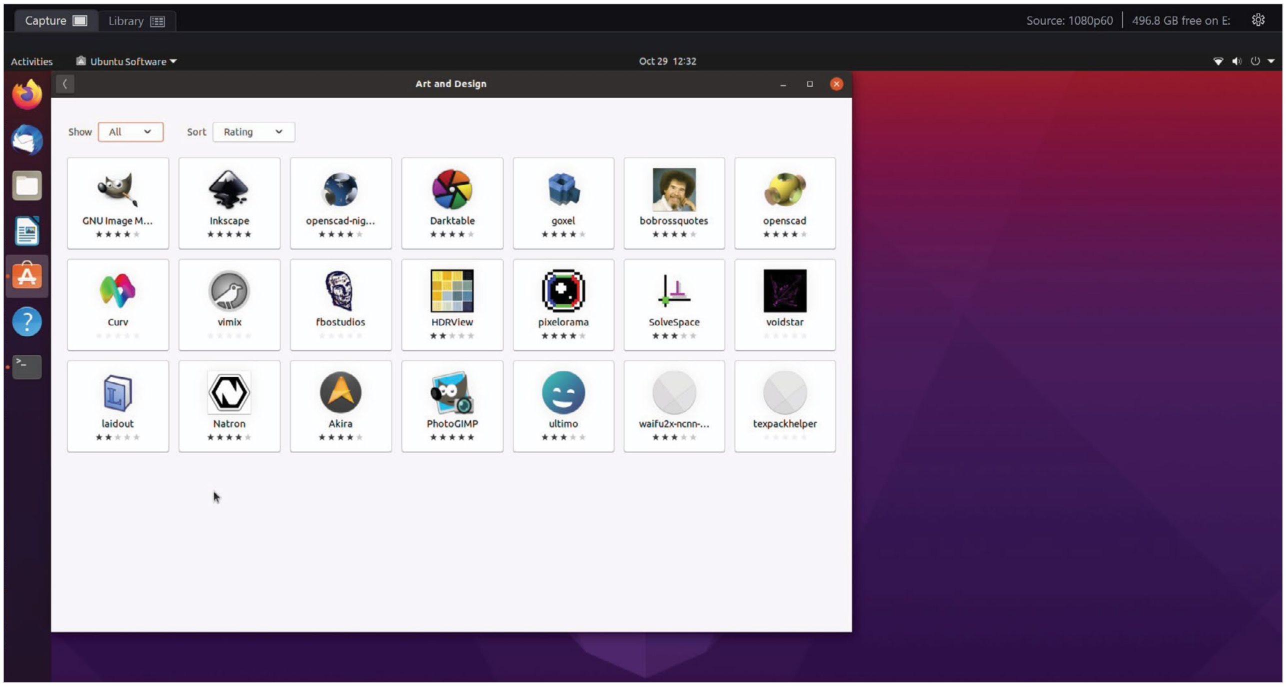


Ubuntu Desktop 20.10 for Raspberry Pi

The grooviest gorilla since Donkey Kong

RASPBERRY PI OS is fine, generally. It's a 32-bit OS though, and the 64-bit version is a work in progress, with features that don't work. If you've got the 8GB version of the Pi 4, you might be frustrated at only being able to use 4GB of that lovely RAM, but Ubuntu has come to the rescue with a Pi port of 20.10 Groovy Gorilla that's fully 64-bit, and a great desktop experience.

Does this make the Pi 4 (or the new 400 model) a proper desktop computer now, or do we have to wait for the inevitable port of Windows for that? Apple's M1 processor shows what's possible with ARM chips when you know what you're doing with them, so perhaps we are looking at the future. Windows on ARM in laptops is coming along, and the power saving they offer over x86 is worth it if you don't need or want the brute force.

Version 20.10 isn't an LTS release of Ubuntu—that was the previous 20.04 (also available for the Pi, but only as a 32-bit OS), but you'll get support until July 2021. It's based on the 5.8 Linux kernel, and the default desktop is Gnome 3.38, along with custom gorilla/raspberry wallpaper.

Installation is a breeze thanks to the Raspberry Pi Imager. This app, which runs on Windows, macOS, and x86 Ubuntu, allows you to install any supported OS from its list, or from an ISO, onto a microSD card or USB SSD (it's a great use for all those 128GB drives we have hanging around following upgrades). Happily, Groovy Gorilla is on its list, so it will download and install automatically, ready for you to pop the card into the Pi (or connect the USB SSD). We installed it on a V10, A1 card— not the fastest out there—and got a boot time of one minute three seconds from power on to desktop (with auto-login switched on). Installing it onto a SATA SSD in a USB 3 caddy (you'll need to update your Pi's bootloader in Raspberry Pi OS to do this, and it's also choosy about which enclosures work) gave a boot time of 48 seconds. The write speeds increase most when using an SSD, we suspect.

Even when running from the microSD card, however, a Pi 4 8GB under Ubuntu is a perfectly usable machine—and this tells you about how nippy the Pi 4's card reader slot can be. Groovy Gorilla comes with Firefox, Thunderbird, and LibreOffice installed, and we were able to add GIMP, Inkscape, and Scribus easily. Signing into a Google account was a piece of cake, and it's perfectly possible to have several of these apps open at the same time. We could do our job—web browsing, email, word processing, and a little bit of light photo editing—perfectly well on one of these. Anyone who does 3D rendering for a living is going to want to look elsewhere though, and Microsoft and Adobe software is right out.

With its ability to output to two 4K screens at the same time and quad-core CPU, the Pi 4 has always looked like a desktop replacement in waiting. With this Ubuntu release, it finally tips over the edge. You really can do a day's work on this, as long as your job isn't doing special effects for 8K video, and it's probably the best desktop experience on the tiny computer. **–IAN EVENDEN**

VERDICT
8

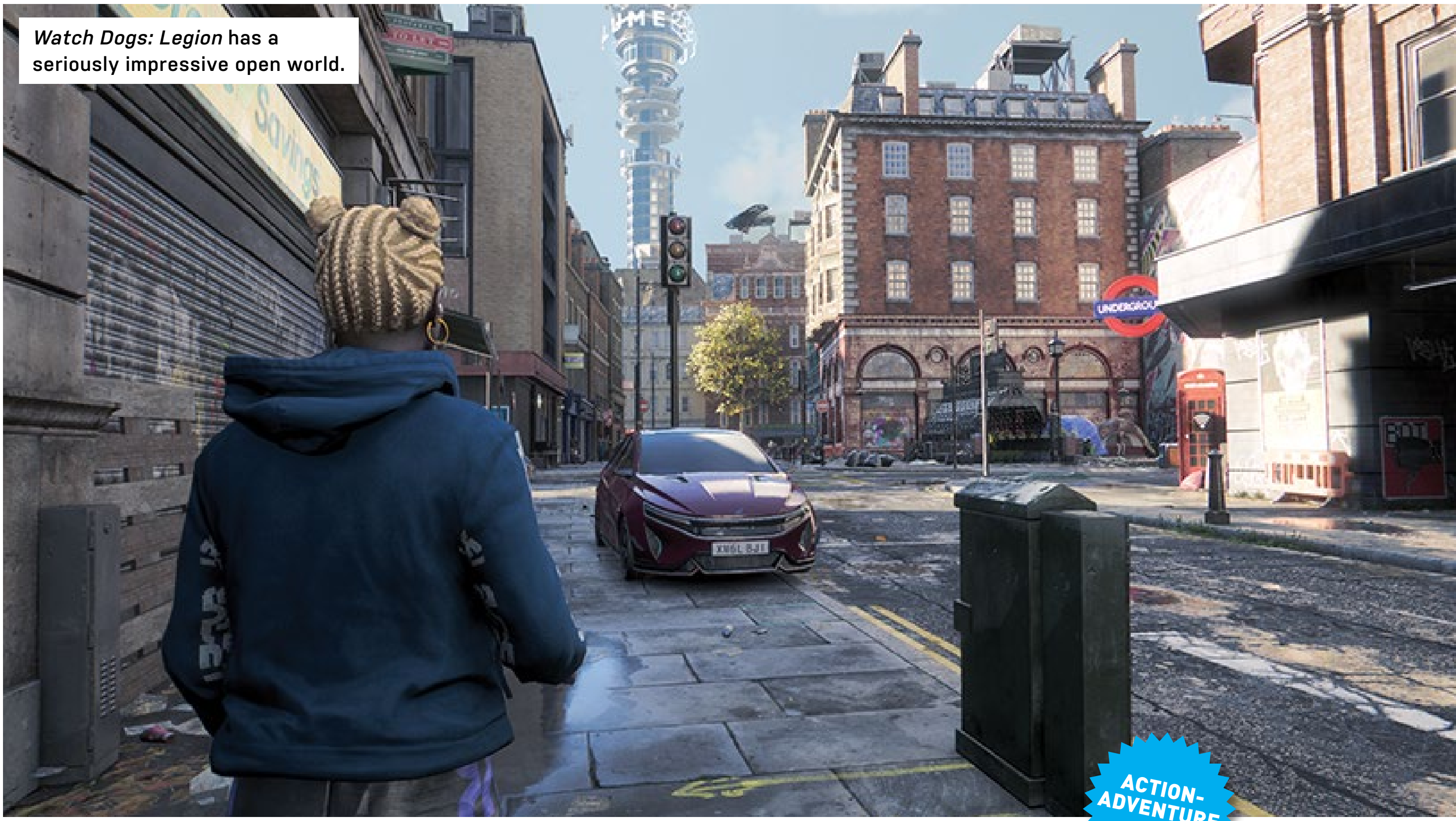
Ubuntu Desktop 20.10

GROOVY Proper 64-bit desktop OS; great selection of open-source apps.

ROCKY Usual Linux moans; slightly sluggish on Pi.

RECOMMENDED SPECS Raspberry Pi 4 or 400. 4GB RAM.

$Free, ubuntu.com



Watch Dogs: Legion has a seriously impressive open world.

ACTION-ADVENTURE

Watch Dogs: Legion

Hacking on the streets of London

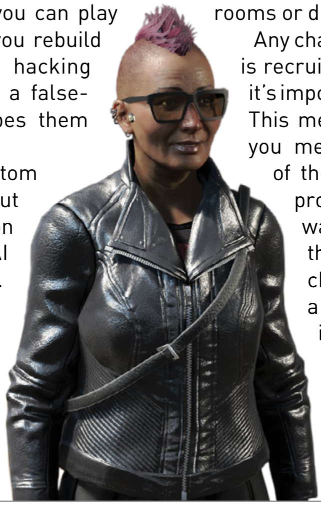
UBISOFT'S OPEN-WORLD London is quite an achievement, even if its inhabitants frequently speak in a way that would make even Guy Ritchie think the dialog coaches had gone a bit far. It's a shame, then, that such a fine representation of a near-future capital city has been tethered to such an unrelentingly grim game.

There's no main character this time around, a very good thing when you remember the sullen Aiden Pearce from the first entry in the series. While you create a custom character at the beginning of the game, you can play as anyone you meet as you rebuild the DedSec white-hat hacking crew from scratch after a false-flag terrorist attack wipes them (almost) out.

Starting as your custom character, you're sent out onto the streets of London by a bizarrely profane AI to recruit new members. The near-future setting allows the realization of all sorts of conspiracy theories, and London—presumably the rest of the UK too—is being run by the PMC Albion, turned into a surveillance state with checkpoints, drones, and itchy-trigger-finger armed response. There's also another crew in town, Zero Day, who you'll need to take down. *Watch Dogs'* genetic makeup has received a heavy dose of *GTA* DNA—stealing cars and setting off urban mayhem is a major part of the fun on offer. Stealthy infiltration of company premises makes up the rest, using vents, camouflage, or spider-bots to obtain information from locked server rooms or dingy basements.

Any character you pass in the street is recruitable to the new DedSec, so it's important to only recruit the best. This means checking out everyone you meet, and while the majority of the cast is fairly normal in a procedurally generated sort of way, there's frequently a skill that you just can't resist. We chose our initial character, a zoo worker who had been in trouble with the police, simply because she came with an MP5. It wasn't a silenced model, though, so we were delighted when an ex-special forces type appeared in our basement HQ with just such a weapon as a reward for having the Ultimate version of the game. The first person we recruited was a judge who could get out of custody more quickly than other characters. You get information on hobbies, voting records, employment status, and a rare character may have a special ability, such as a rideable drone, a grenade launcher, or "tough drunk," which decreases melee damage, while another may have a flaw that makes them an absolute liability. Or both. You can take this as far as you like, rejecting a useful character on the strength of their political preferences or the fact they attend furry conventions (more common in London than you'd suspect, apparently) even though these things have no bearing on how they operate when you're in control.

And the great thing is you get attached to them. Set the game up the right way, and they can suffer from permadeath, reincarnating you as another member of your crew rather than restarting from the last checkpoint. Recruit a few expendable members and send one in as a scout. There's a side-quest to perform to recruit



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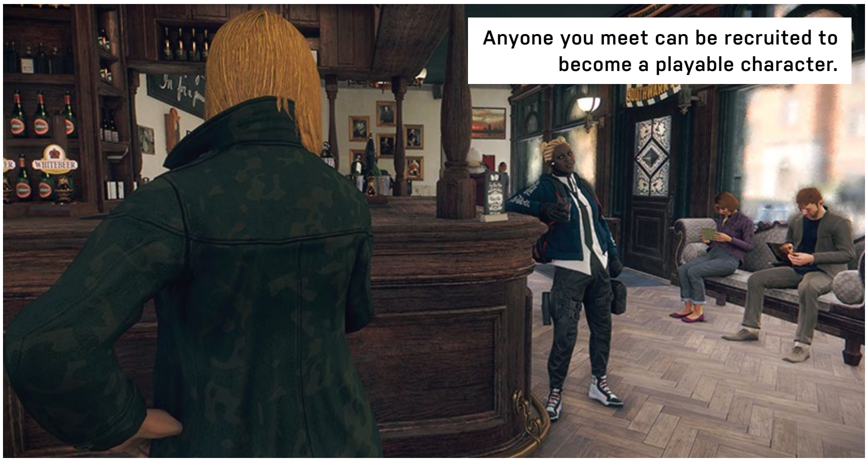
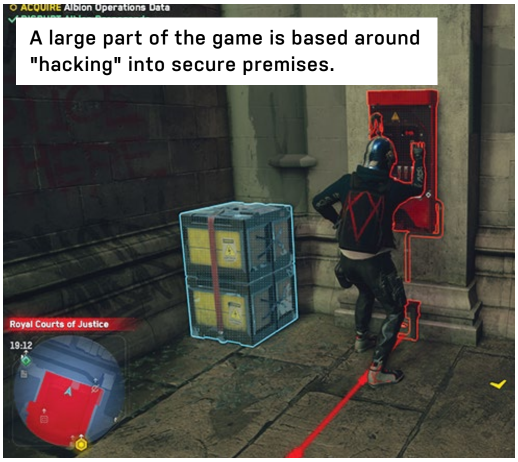
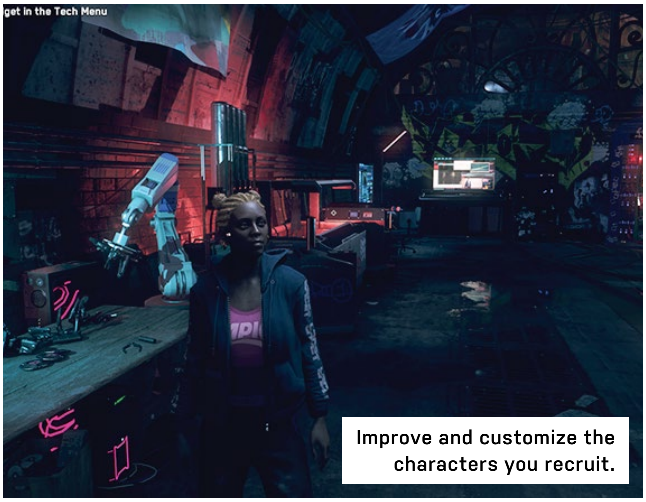
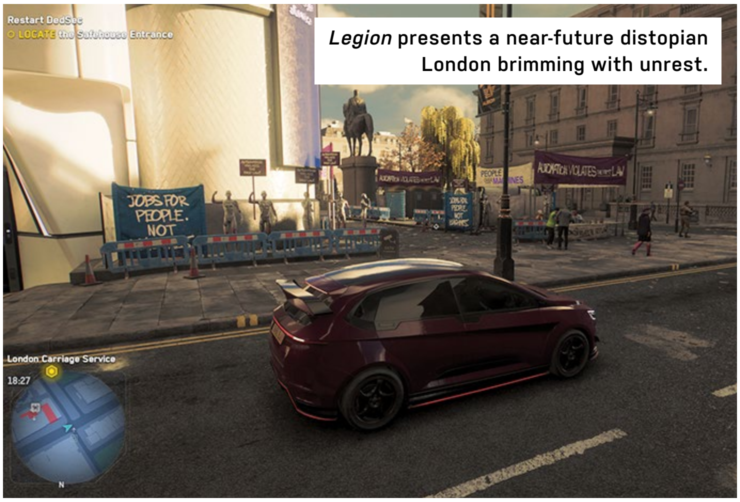

Anyone you meet can be recruited to become a playable character.



A large part of the game is based around "hacking" into secure premises.



Improve and customize the characters you recruit.



Legion presents a near-future distopian London brimming with unrest.

new members, but your actions go deeper than that. Each person has friends and relatives, and if you helped their friend, or beat them up, they'll remember and change the way they react to you.

All this world-building is in service to yet another open-world Ubisoft game, however, and we really don't want to be saying this next month too. Missions are repetitive, mostly reliant on stealth infiltrations that become easier as you upgrade your spider-bot. Adding points to the drone hijack skill becomes one of the best things to do, as it gives you a way to fly around the city rather than using a car and being placed at the mercy of the floaty driving model, artificially stupid traffic, and poor selection of songs on the radio (the inclusion of real-world podcasters does a lot to make up for this, however). There are also some bugs, from the amusing—such as characters getting stuck in melee animations—to the game-breaking that prevent missions from being completed. Hopefully, these'll be patched out quickly.

Firefights aren't really the point of the game. If you do get into one, it's better to take advantage of what's around you and turn drones and turrets on your pursuers from deep cover, though combat mechanics have improved, and it's possible to recruit professional hitmen, spies, and members of Albion to your cause to use as enforcers while keeping other characters' consciences clean.

Then there are the weird *Pipe Mania*-style network-bypass puzzles that make up so much of the "hacking" you do. They were a bit tired when used to open doors in *BioShock*, but it's good to see *Legion* having a bit of fun with them, expanding them to enormous sizes so you need to run with your spider-bot or hijack multiple security cameras to see the extent of them. There are even times when you're asked to complete them while under fire. It's not that we expect hacking to be a matter of holding down a button—video games have yet to make the Terminal entertaining—but pipes? Again? Really?

This game is a strange conglomeration: It's enormously political in a way certain sectors of the population may not appreciate; it's one of the best recreations of a virtual city we've yet seen. However, there's frequently one foot stuck in the past, with changes that can seem like a step back, like the removal of *Watch Dogs 2*'s earbuds that let you take tunes with you. It also has the most miserly selection of Ubisoft Club rewards we can remember, with nothing of non-cosmetic use apart from a currency boost—with which you can buy mostly cosmetic items. There are the usual myriad Ubisoft collectibles too, which some despise but others see as a way of exploring and learning the world.

When the game gels, however, and you're riding past the London Eye on a cargo drone to escape gun-toting security forces, or driving over a street so shiny with ray-tracing effects it looks like ice, it's probably the best open-world game of the year. Until next month. **–IAN EVENDEN**

VERDICT

7

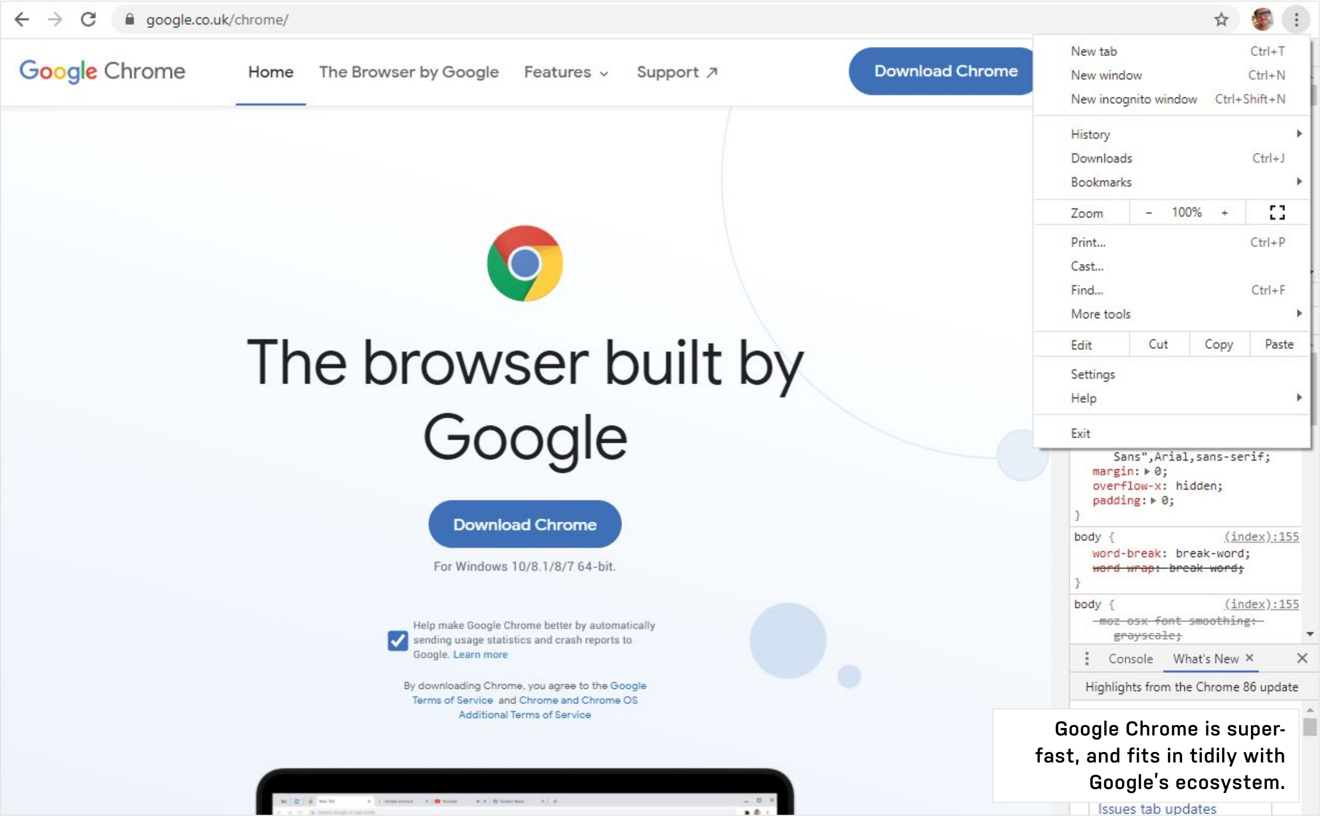
Watch Dogs: Legion

+ HACKNEY Superb recreation of near-future London; plenty of character, and characters.

− HACKNEYED Pipe puzzles; lack of music on offer; repetitive missions.

RECOMMENDED SPECS CPU, Core i7-4790 / Ryzen 5 1600. RAM, 8GB. GPU, GTX 1060.

$60 www.ubisoft.com, M-rated



The browser built by Google

Download Chrome

For Windows 10/8.1/8/7 64-bit.

☑ Help make Google Chrome better by automatically sending usage statistics and crash reports to Google. Learn more

By downloading Chrome, you agree to the Google Terms of Service and Chrome and Chrome OS Additional Terms of Service

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Highlights from the Chrome 86 update

Google Chrome is super-fast, and fits in tidily with Google's ecosystem.

Google Chrome vs Mozilla Firefox

Who browses the browsers?

FOR THE LONGEST TIME everyone used Microsoft Internet Explorer, and then one day, around 2013, the world woke up and everyone was using Chrome. How did that happen, and should we care? Google launched Chrome in late 2008, when Firefox from the non-profit Mozilla was pootling along at 30 percent market share and IE at a seemingly insurmountable 70 percent share. Jump forward four years and Chrome had half the market—and increasing—with IE and Firefox fighting for second and third place.

Chrome's unstoppable success seems like a combination of agile development—quickly embracing the latest open-source technologies and standards—Google's dominant search position, its growing online tool suite, and its mobile success with Android. Google is everywhere, bringing Chrome with it.

Firefox is the sweetheart of the open-source world, the default browser in most Linux distros. It was spun out of the Mozilla Suite, which was in turn a fork of Netscape Communicator, around 2002, and has been in constant development ever since by Mozilla.

You can spot immediately that the origins of both browsers are almost diametrically opposite. Chrome being open source is largely meaningless: It's just a form of development that corporations now deem most cost-effective; it still has proprietary parts. While Google is a corporation largely funded by advertising and tracking your internet use through its browser, devices, and services, Mozilla is non-profit, funded by contributions, service subscriptions, and search-bundle deals—oddly largely with Google—and is dedicated to internet privacy and a free, open internet. Not being judgy, but Google did drop its "Don't be evil" motto too. That's not to say it's one of the bad guys, but it's something to keep in mind as it tracks your every move...

Modern browsers are complex, more akin to a mini operating system, so much so that Google launched Chrome OS built around its Chrome browser. A key element for a modern browser is parsing HTML5 correctly and quickly—we use html5test.com to test just that.

Chrome uses the Google-developed Blink open-source engine—a fork of Apple's Webkit—and it's in good company, with Microsoft Edge, Opera, and many others choosing to use it too. Alongside that is the Google V8 JavaScript engine. Firefox is very unusual now, as it's one of the few browsers to run its own Gecko engine and SpiderMonkey JavaScript engine. Firefox scores 464 and Chrome 476 out of 555 in the compatibility test, pitching them close for web compliance.

We should also test JavaScript and Web Assembly—a newer language envisioned to replace JavaScript—speed with a couple of benchmarks. Mozilla Kraken (https://krakenbenchmark.mozilla.org) returns 963ms with Chrome, and 873ms on Firefox, but it's clearly biased. There's also https://browserbench.org/JetStream that's built on Kraken with more tests. This put Chrome firmly ahead with a score of 113 against Firefox's 91.

We also wanted to run some direct visual tests; as we spend most of our days in a browser, optimal graphics are important. WebGL is used for 3D rendering. Our first test is from webglsamples.org. Chrome remained smooth at 34fps while Firefox struggled down at 13fps.

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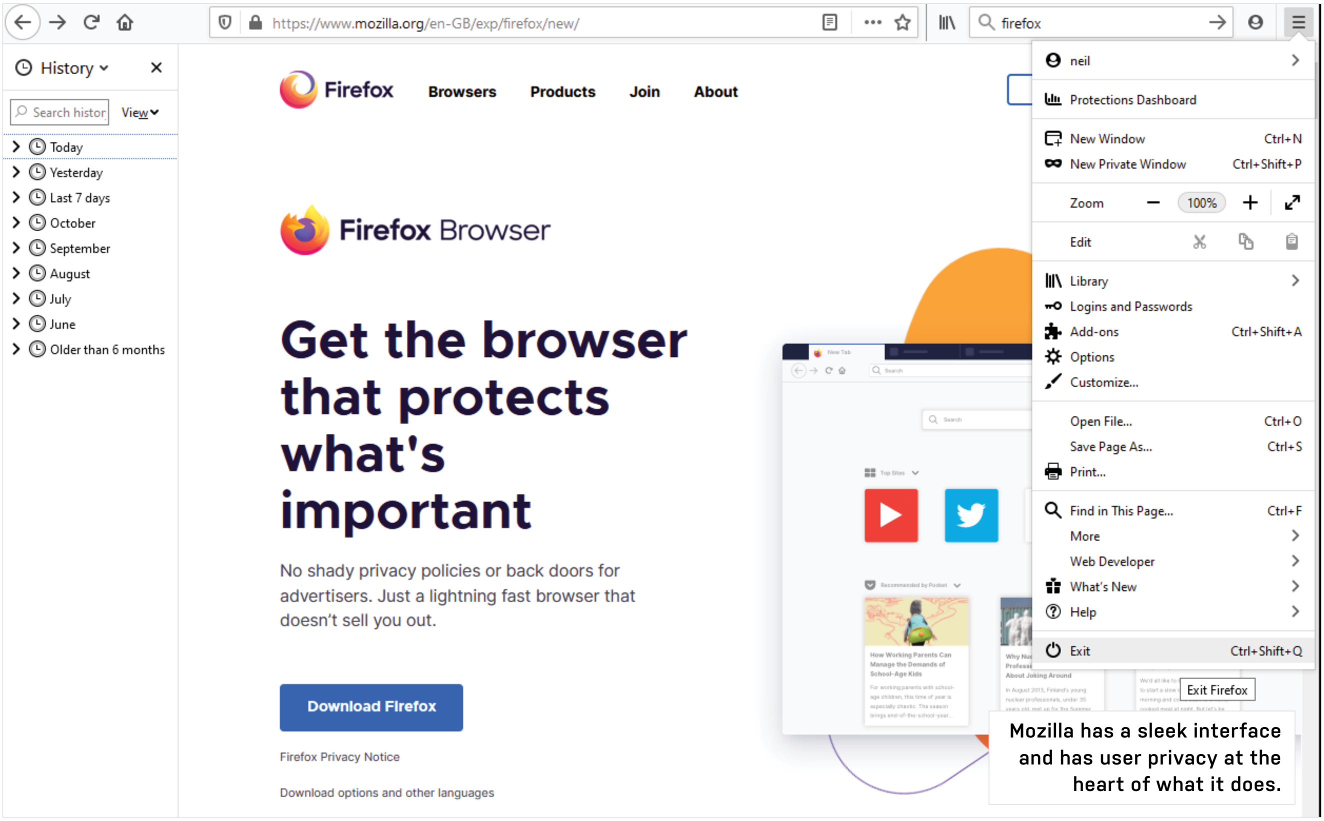
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Customize...
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Save Page As... Ctrl+S
Print...
Find in This Page... Ctrl+F
More
Web Developer
What's New
Help
Exit Ctrl+Shift+Q
Exit Firefox

Get the browser that protects what's important

No shady privacy policies or back doors for advertisers. Just a lightning fast browser that doesn't sell you out.

Mozilla has a sleek interface and has user privacy at the heart of what it does.

© MOZILLA

Our other visual test is https://browserbench.org/MotionMark that flings 2D visuals at the browser's canvas. Again Chrome's 471 appears to smash Firefox with 270 and would be in line with the WebGL test, but looking at individual test scores Firefox is as fast if not faster, bar one "multiply" test that Firefox fails.

Modern PCs have buckets of memory so its use isn't too concerning, but it's another area we can measure. Chrome used to be known as a memory hog, but it seems Google has done a lot of good work in this area. Firefox at startup uses 246MB and running JetStream this peaks at 1,462MB, while with Chrome initial start-up was 219MB, and running JetStream peaked at 1,112MB. Doing basic browsing over the same sites with the same tabs, Chrome used 802MB and Firefox 816MB.

USER-FRIENDLY

Shifting our focus to usability, both Chrome and Firefox offer a similar user experience, with streamlined, minimal tabbed interfaces that can be customized with user-configured toolbars and icons. Personally we prefer the new Firefox Library that combines all browsing activity and a slicker History system. Google uses an awkward style for its Downloads and History, which seems tailored for mobile browsing. Tab management on both is excellent, able to multi-select, move, close, and restore sessions. They both have nods to accessibility, and decent zoom options and keyboard navigation.

Both browsers offer Themes and Extensions, and both recently updated the plugin systems—much to the annoyance of plugin writers. The move was to increase security but restricts access to certain APIs, though ultimately there was a compromise. Chrome being the more widely used, it has more plugins, though the quality of many is questionable. Firefox will have most of the plugins you're after but will likely miss new trends such as Netflix Party and the like.

Both browsers also offer a form of roaming account and synchronization. Your Google account will literally track everything you do and everywhere you go. Chrome has cutting-edge telemetry developed as only a world-spanning multi-billion-dollar corporation can, but it also syncs your passwords, bookmarks, and plugins. So it's all good. Mozilla's Firefox Account does all the synchronization but without the tracking part: It's now offering a VPN privacy service, enhanced password manager, data-breach monitor, and notification service.

From a raw performance perspective it's hard to argue with Chrome: It's entirely dominant, even with memory use now. The Chromium project is used by almost all browsers outside of Apple's Safari, so it attracts huge amounts of development time, and it shows. If you use Google services then it ties your account directly to these, and its integrated services make for a seamless experience. But if you want a browsing experience free of corporate monitoring, then Firefox is a solid and dependable alternative. We also prefer its interface. **–NEIL MOHR**

VERDICT 9

Chrome v86.0.4240.198

SHINY So fast; reasonable memory use; integrates into the Google ecosystem.

TAINTED They're watching, always watching; stupid history design.

RECOMMENDED SPECS Windows 7, Pentium 4 type CPU with SSE2.

$Free www.google.com/chrome

VERDICT 8

Mozilla Firefox v82.0.3

HOT TUB Mozilla has your privacy back; interesting extra VPN services; good HTML5 compliance.

SPICEY RING Held back by its graphical performance; misses newer plugins.

RECOMMENDED SPECS Windows 7, 512MB (2GB for 64-bit), Pentium 4 type CPU with SSE2.

$Free www.mozilla.org/firefox

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Gaming Server Case
> Sleeper Build
> Back to Tech

Server Rack System?

Hey Zak! Glad to see *Maximum PC* is back to full length, and I hope you're staying safe and healthy. I had a quick question about a rack-mounted chassis. The parts I'm using are essentially a gaming PC build, but I can't recall *Maximum PC* ever covering this type of funky build. I'm looking at cases, but there's a lot to cover in terms of what size (2U, 4U—how much clearance will I need and what should I prepare for?); I'm not even sure if I can mount an AIO in a rackmount. I'd love a recommendation (or even a full-length article with the amount of confusing options out there) if you know of any?

I work in sound design, so also any way of reducing the sound from the chassis would be a plus! **–Tzvi**

EDITOR ZAK STOREY RESPONDS: Oh this is a tricky one, I've actually toyed with this idea a few times, but it's so difficult getting server racks in for review, it's just never been possible on our end. So ideally you'd need a 4U rackmount case. 3U does support full-size GPUs to my knowledge, but if you're looking to install an AIO liquid cooler, then 4U is the way to go, as the extra height/internal volume gives you more clearance for larger fans. Most 4U units support a single 120mm fan up front, and then multiple 60mms or 80mms in the rear. That said, there is a Rosewill 4U server chassis on Amazon that does have support for 2x120mm intake fans up front, so you could theoretically stick a 240mm AIO in that. It's affordable(ish) too, $138.44 at the moment. The front end of it is intense though: A locked filtered grille.

As for reducing noise, it's really going to be the trick with this style of build. If money's no object (I know that's rarely the case), I'd recommend running a 120mm AIO for the CPU, and then a hybrid AIO/air cooled GPU as well, unless it's a fairly low-end chip. I mean, depending on what you're running program-wise when you're actually recording or working with sound, the GPU may be fairly quiet anyway. So that might be overkill, but it certainly helps to reduce temps and noise because of it.

Personally, though, whatever chip you're running, I'd drop the stock voltage a touch, drop the frequency, and then set the fan curves so they sit at a permanent fixed RPM that's suitable for your work until the CPU hits 75C or so. Control it all in the BIOS, and make sure you get some Noctua NF-F12s or Corsair ML120 Pros to keep the noise to a minimum. Also I'd recommend a solid AIO; some of them can rattle quite a bit, or gurgle, especially at higher temps (my EK one I'm currently using is a nightmare for this). Then of course you've got noise-dampening options too such as foam inserts, which you could stick inside the server rack if it has a door.

Thanks for the feature idea though. I didn't know Rosewill sold server rack cases, so hopefully we should be able to get one in for review/a build, as this is something we're seeing a lot more of out there.

Sleeper Builds

Hi there, Have you ever thought about doing a sleeper build in an old beige PC tower? I know the cases are fairly easy to come by, but I've never seen someone build one with just stock parts before. They look sick! **–Jamie Marchant**

EDITOR ZAK STOREY RESPONDS: I love the idea of sleeper builds. Just the whole notion that you don't have to have something that looks incredible for it to be powerful, and the almost shock factor that comes with it as well, it's tantalizing and very tempting. If I wasn't such a stickler for build aesthetics I'd consider it myself.

There's also considerable challenge involved when it comes to building in a system like that. For one thing a lot of the old beige tower cases are somewhat smaller than the cases we use today, so many of them actually don't support full-height graphics cards, or even full-length ones. On top of that there's a lot of superfluous stuff and old design decisions incorporated into the interior—floppy disk bays, power supplies mounted in the roof, multiple hard drive cages taking up the front.

↘ submit your questions to: comments@maximumpc.com

Then there's the cooling as well, and this is perhaps the biggest challenge out of the lot. Again because of the hardware that was out there at the time, chassis cooling wasn't quite so important as it is today. Most processors and graphics cards didn't need vast tri-fan heatsinks or chunky AIO solutions either, and then there's a lack of intake airflow support too—it's a whole thing. Even back then, if you were running top-end hardware, the likelihood was that you had a fairly solid case outside of the world of the beige.

And lastly, you've got to find a chassis like that to build in. There are certainly no brand-new cases out there, so a lot of the time, unless you have one stuck down in your basement somewhere, actually sourcing the case is going to be a problem. Your best bet for sure is eBay, or through second-hand resellers.

That's not to sound so defeatist, however; there are plenty of work-arounds, it just requires a significant amount of modding. Theoretically you could get a case like that ready fairly quickly. Cut out the hard drive cages and the 5.25-inch bays to give you more clearance internally, and if you could make some form of raised feet, you could even cut out the bottom of the chassis to allow for twin 120mm fans, which although not ideal, would give you access to a 240mm AIO at the very least.

Getting Back to Tech

Zak, Since COVID began I know you've been doing a very difficult job and to be honest, you have done very well with keeping the information flowing in a tough time. But dude... Norway? And now an article about your cars getting dinged? You might be a little off-track with some of the stuff ,and I know you want to make a more human presence with your readers, but damn bro. I would rather hear more about ARM or maybe a review on "True" giga(byte) per sec routers. Just my two cents... now get back to work! **–Rich Gillis**

EDITOR ZAK STOREY RESPONDS: I love emails like this, so thank you for writing in. I genuinely do appreciate constructive criticism like this—it helps to point out where we're going wrong, and how we can improve the magazine for you guys.

I think the limiting factor in Labnotes is actually the word count on that column, because both of those stories that I wrote about do indeed link to tech, albeit very subtly, and that's kind of the common thread in Labnotes as a whole. The Norway thing was me trying to better allocate my time away from gaming, calibrate my PC build accordingly, and then take advantage of modern-day tech and software to make the language-learning process easier. The car thing was sort of looking at how tech and cars have become so interwoven in the last few years, and why that's pushing me away from classic muscle cars and VWs—something quite pivotal to who I am—to cars that protect my family and myself through the incorporation and development of tech and PC hardware that we support here too.

But I completely understand where you're coming from, and you are right. It is difficult at the moment, especially as we're no longer situated in an office (Future, our parent company, has both re-opened and closed its offices again, as COVID case numbers have fallen and risen with the second wave), so we don't sit around with the other tech mag teams anymore, we don't get to tinker as much with tech in our off-time, and we don't get to see all this great hardware come in either (most of it gets shipped to individual writers). Which is a shame, and it's why Labnotes has become quite challenging to write, and why you've seen it get re-formatted I think about three times so far since I first joined.

But I absolutely hear you, we'll knock the personal columns back a bit, and get ourselves a bit more grounded in PC hardware than we have been for some time. I'm not saying we won't talk about things like this in the future, just that we'll scale back that frequency a bit.

Subscription Issues

Hi Zak, I'm still having problems with missing issues and my subscription, and customer service at Magazines Direct is just utterly useless. Is there anything you can do?

–Robert Green

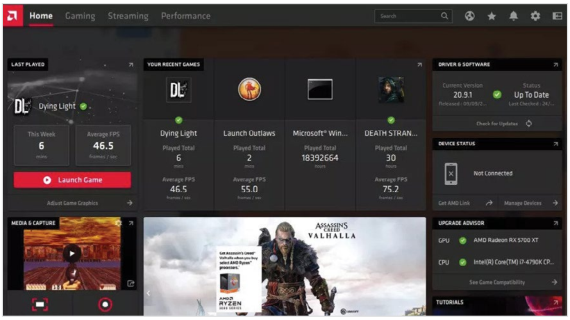
EDITOR ZAK STOREY RESPONDS: Absolutely Rob, And the same goes for anyone else: If you want to drop me an email directly at zak.storey@futurenet.com with your subscription number and what the problem is, I can actually push these on internally to our head of subs. We've had some serious meetings lately about this, because I'm still not happy with how things are being handled, and we now have a dedicated person at Future, who can push complaints on urgently and give them a high priority.

So if you do have any issues, please drop me a line directly, and I'll lean on our subscription team to resolve the issue as best they can. It's very frustrating, and I want to apologize for that.

On top of that, if anyone has any tech questions or PC problems, feel free to fire them my way! Although no promises that I won't publish them here if they're particularly juicy tech queries. If I can't answer them I'll forward them to the ol' Doc. ⏻

[NOW ONLINE]

A GUIDE TO AMD GPU SOFTWARE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MEDIA & CAPTURE
ASSASSIN'S CREED VALHALLA
AMD RYZEN
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GPU
AMD Radeon RX 5700 XT
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Intel(R) Core(TM) i7-4790K CP...
See Game Compatibility
TUTORIALS

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The software that comes with AMD graphics card drivers is a great way to tweak and enhance game performance, and yet nobody's talking about it. Matching and sometimes surpassing the Nvidia Control Panel for features, AMD Radeon Settings lets you do pretty much anything—from fine-tuning in-game graphics to monitoring your GPU temperatures and even overclocking.

Here we'll go through the best AMD Radeon Settings. Of course, you'll need an AMD GPU to use this powerful tool.

Read the full article here: https://bit.ly/AMDDrive

THE BUILDS

BUDGET

WE'RE IN A BIT OF AN ODD PLACE at the moment. There's a huge demand for new products that's far outstripping the supply, and on top of that, because of Black Friday (we're actually writing this two days before), prices have annoyingly crept up across the vast multitude of PC parts, as retailers prepare to decrease the price again to simulate a sale-like atmosphere. This is one of the big reasons why we always recommend going to a site like *Tom's Hardware* or *PC Gamer*, or even *TechRadar* when it comes to sourcing good deals. These boys and girls do the legwork for you, to hopefully sift the wheat from the chaff, so to speak.

Unfortunately, despite our best efforts, and because of these market shenanigans, we've seen both of our builds steadily increase in price, with the AMD build increasing by an incredible $53, and the Intel build up $51. This is even with some hefty concessions made on both builds in terms of performance. We've had to drop to a 250GB Samsung 980 Pro in the AMD build, down from the 500GB we featured last issue, and change out the memory to some OLOy 3,000 MHz RAM instead. Our Intel machine has also seen some significant change, with us going for the positively old 500GB Samsung 970 Evo M.2 PCIe 3.0 SSD (still a darn quick drive), and changing to the Core i5-10400F as well, which lacks integrated graphics. Most frustratingly, the 500GB 970 Evo is still cheaper than the 256GB XPG SX8100 we featured last issue. Just be wary: If you do plan to build this rig without the graphics card, you will need to opt for the standard Core i5-10400 instead, or rummage around your spare parts bin for a GPU.

There is one additional saving you can make across both builds, and that's opting for the white variant of Corsair's 4000D Airflow. It's currently available for $70, down from $80, and while it's not a revolutionary saving by any length of the imagination, it does make those price increases a little more bearable.

AMD INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$70
PSU	450W Gigabyte GP-450B 80+ Bronze	$40
Mobo	ASRock B550M Pro4	$90
CPU	AMD Ryzen 3 3100	$130
GPU	XFX Radeon RX 5500 XT 4GB	$180
RAM	16GB (2 x 8GB) OLOy DDR4 @ 3000 MHz **NEW**	$50
SSD	250GB Samsung 980 Pro M.2 PCIe 4.0 **NEW**	$80
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD	$30
OS	Windows 10 Home 64-bit OEM	$25
Approximate Price:		**$695**

INTEL INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$70
PSU	450W Gigabyte GP-450B 80+ Bronze	$40
Mobo	ASRock B460M Pro4	$80
CPU	Intel Core i5-10400F **NEW**	$172
GPU	MSI GeForce GTX 1650 Super Ventus XS OC 4GB	$170
RAM	16GB (2 x 8GB) ADATA XPG Z1 DDR4 @ 3000 MHz **NEW**	$51
SSD	500GB Samsung 970 Evo M.2 PCIe 3.0 **NEW**	$60
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD	$30
OS	Windows 10 Home 64-bit OEM	$25
Approximate Price:		**$698**

MID-RANGE

AND HERE IS WHERE THINGS start to get tricky, and this is mostly down to the all the newly released hardware out there. Unfortunately, although AMD's Ryzen 5 series and Radeon RX 6000-series cards, and Nvidia's 3000-series cards are impressive products, there just isn't any of them out there. Demand has far outstripped supply. We're still hearing rumors that Nvidia isn't expecting supplies to keep up with demand until spring 2021. And it looks to be the same for AMD too, both for its Ryzen chips and its GPUs. That's crazy—at any other time we'd call all of these paper launches, but it seems that there's just so much demand because of the pandemic that it might not even be the case.

We're starting to see the end of supply for the older series parts too, including 2000-series cards from Nvidia, 5000-series GPUs from AMD, and Ryzen parts. This is a serious issue, because if you actually want to buy a graphics card in North America right now, you sort of can't get one—not from Newegg, Amazon, or anywhere. You'll only really find these cards on eBay or Amazon at super-inflated prices from dubious third parties or scalpers. Yay.

To that end changes here are fairly subtle. We've swapped out the Corsair A500 air cooler in our Intel rig for a Cooler Master Masterliquid ML240L. The A500 had popped back up to $60, and considering this is a 240mm AIO, the choice was obvious. On top of that we've also gone from our MSI Radeon RX 5700 Mech 8GB to a GeForce GTX 1660 Ti 6GB instead, since there are no 5700s below the $400 mark—in fact there's seemingly no GPUs at all around the $300 price mark right now.

For our AMD rig we've had to opt for the stock Ryzen 5 3600 to save a bit of cash, grabbed another 5700 (the cheapest we could find), and changed over to some more OLOy memory as well. Even with these savings our AMD build is $101 more than it was last issue, while the Intel build a less eye-watering $30 more.

AMD INGREDIENTS

PART		PRICE
Case	Lian Li PC011-Dynamic	$140
PSU	650W Corsair CX650	$76
Mobo	Asus TUF Gaming X570-Plus	$182
CPU	AMD Ryzen 5 3600 **NEW**	$223
Cooler	Corsair A500	$63
GPU	MSI Radeon RX 5700 Gaming X 8GB **NEW**	$394
RAM	16GB (2 x 8GB) OLOy DDR4 @ 3600 **NEW**	$57
SSD	500GB Gigabyte Aorus Gen4 M.2 PCIe 4.0	$90
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD	$30
OS	Windows 10 Home 64-bit OEM	$25

Approximate Price: $1,280

INTEL INGREDIENTS

PART		PRICE
Case	Lian Li PC011-Dynamic	$140
PSU	650W Cooler Master MasterWatt 650	$86
Mobo	MSI MPG Z490 Gaming Plus	$170
CPU	Intel Core i7-10700	$325
Cooler	Cooler Master Masterliquid ML240L AIO **NEW**	$64
GPU	MSI GeForce GTX 1660 Ti 6GB Ventus XS OC **NEW**	$334
RAM	16GB (2 x 8GB) Team T-Force Delta RGB @ 3200	$65
SSD	500GB WD Black SN750 M.2 PCIe 3.0	$73
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD	$30
OS	Windows 10 Home 64-bit OEM	$25

Approximate Price: $1,312

TURBO

SADLY THIS TREND CONTINUES in our Turbo builds, once again because of a lack of supply, and for the first time in the history of this segment, we have no alternative solution to our graphics card woes. If you want a high-end GPU right now, whether that's one of the brand-new ones from AMD and Nvidia, or the last generation's, there simply isn't any. The best you can do is find somewhere that will let you pre-order the card you want, but in all honesty, you'll likely be stuck in a queue for a considerable length of time.

The Gigabyte GeForce RTX 3080 Eagle is still our card of choice for the time being. There is some justification for going with an AMD Radeon RX 6800XT for the Ryzen system due to their shared memory capabilities, but you really shouldn't purchase one for more than the going retail price. The more we encourage scalping as a community, the worse it will become.

Outside of the shortages, we've been able to make a few changes. For our AMD system we've gone with the snazzy Extreme4 X570 board from ASRock, and replaced the ageing 280mm iCUE H115i from Corsair with its latest Capellix-powered 360mm. This comes in at about $20 more, but should keep your processor cool, whether that's the 3950X that you can still purchase, or the AMD Ryzen 9 5950X we'd recommend in its stead. We've also seen some savings in the storage department, which is certainly welcome given everything else going on.

For our Intel system we've gone for a fancier Gigabyte Aorus motherboard, upgraded again to a 360mm AIO for our overclockable chip, and swapped out that old 6TB Seagate HDD (that's no longer available) for a Western Digital Red Pro. Although typically designed for use in NASes, the extra reliability will help long-term, and 6TB of storage is more than enough for your media.

As an alternative, you could opt to go for a dedicated NAS instead; Asustor sells a fantastic two-bay NAS (the AS5202T) for $300, which even comes with twin 2.5GbE Ethernet ports, making it ideal for backing up all of your personal media collections.

AMD INGREDIENTS

PART			PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass		$140
PSU	750W Corsair RM750x Modular PSU		$135
Mobo	ASRock X570 Extreme4 ATX	NEW	$232
CPU	AMD Ryzen 9 3950X		$690
Cooler	Corsair iCUE H150i Elite Capellix 360mm AIO	NEW	$160
GPU	Gigabyte GeForce RTX 3080 Eagle 10G	OOS*	$730
RAM	32GB (2 x 16GB) Corsair Vengeance RGB Pro @ 3600MT/s		$144
SSD	1TB Gigabyte Aorus Gen4 M.2 PCIe 4.0	NEW	$154
HDD	6TB Western Digital Red Pro HDD	NEW	$136
OS	Windows 10 Home 64-bit OEM		$25
Approximate Price:			**$2,546**

INTEL INGREDIENTS

PART			PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass		$140
PSU	850W NZXT C850		$130
Mobo	Gigabyte Z490 Aorus Ultra ATX	NEW	$240
CPU	Intel Core i9-10900K		$540
Cooler	NZXT Kraken X73 360mm	NEW	$160
GPU	Gigabyte GeForce RTX 3080 Eagle 10G	OOS*	$730
RAM	32GB (2 x 16GB) Corsair Vengeance RGB Pro @ 3600MT/s		$144
SSD	1TB WD Black SN750 M.2 PCIe 3.0		$116
HDD	6TB Western Digital Red Pro HDD	NEW	$136
OS	Windows 10 Home 64-bit OEM		$25
Approximate Price:			**$2,361**

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